INTEGRATED EDITION OF THE PETROLEUM ENGINEER

the Petroleum Engineer

FOR MANAGEMENT

JULY 1960

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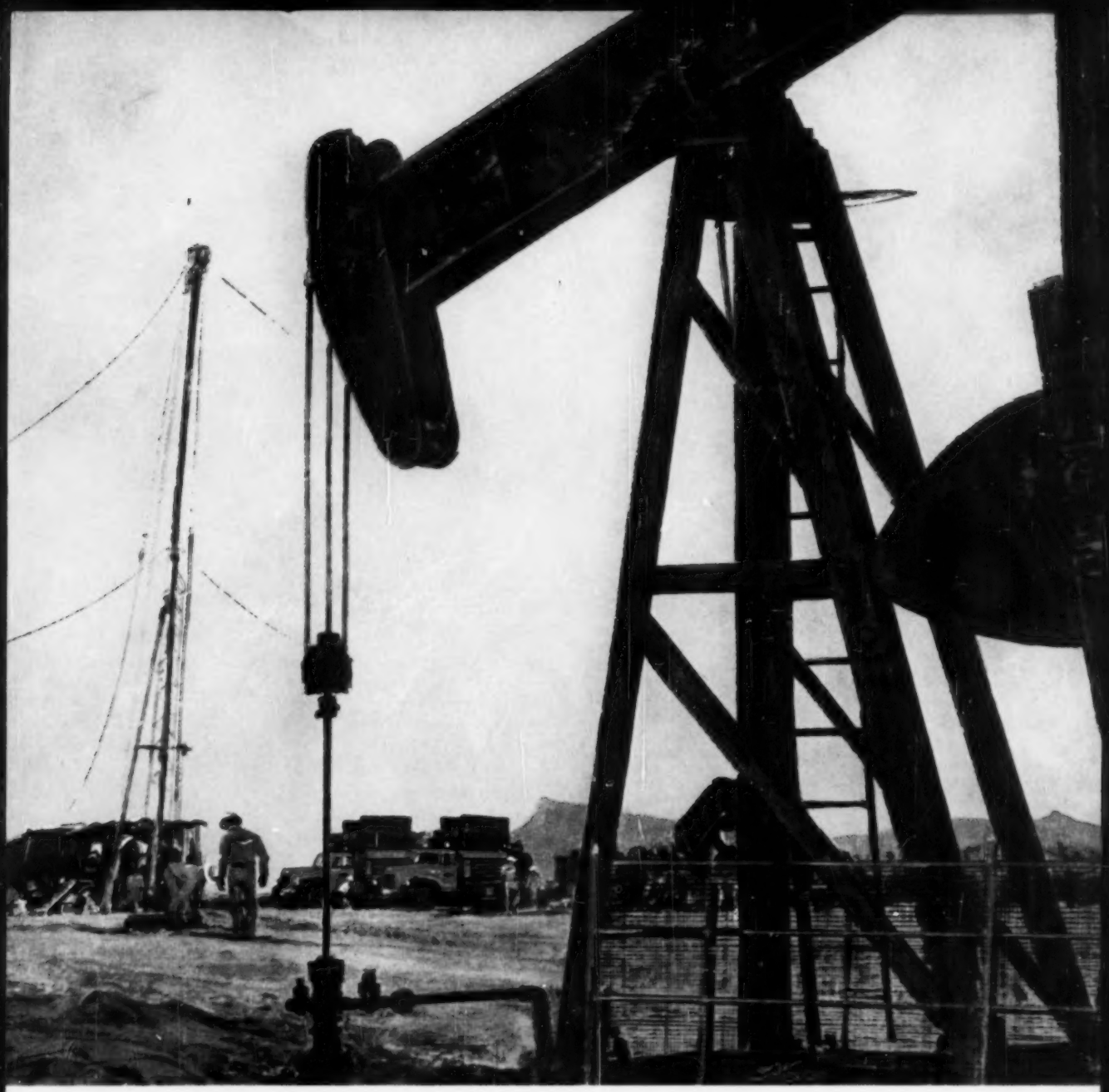

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It is the hope of all of us to be able to communicate better, whether on the job or in our private lives. Communications is one of the great satisfactions of the publishing business. As part of a publishing team serving nearly 40,000 readers with a completely new product each month, we have to send and receive a lot of communiques. You may be surprised (we are gratified) to know the volume of correspondence between you, the readers, and our headquarters office any month, would make a stack head-high to a man eight feet tall.

In the course of a year we hear from over 5,000 of you personally. Your interests are varied indeed, ranging from letters of praise and criticism (we appreciate both types), to requests for tear sheets, reprints of articles, or the name of a manufacturer whose equipment is referred to in the editorial pages or featured in an advertisement. In the past few months you have requested additional information on over 20,000 new equipment, new literature, and advertised products or services. We attempt to handle all requests promptly; but when we seem tardy, I hope you will write me personally. Remember, "the squeaking wheel gets the grease".

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Joe B. Hoode

Publisher

THE PETROLEUM Engineer

FOR MANAGEMENT

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Highlights and footnotes

Earnings Drag. For the second quarter petroleum companies earnings are likely to drop a little below 1959. First quarter, as we showed last month, was almost on dead center compared to first quarter of last year. Most optimistic factor is that prices of products have been firming up some which helps offset the effect of earlier price weakness. It should be added that this trend is not limited to petroleum. It's common to most industries.

Russian Oil. Castro called on Royal Dutch/Shell, Jersey Standard, and Texaco to accept 6000 b/d each of Russian oil for refining in their Cuban plants. The companies refused. Mines Minister Alfonzo Perez of Venezuela made public objection to replacement of Venezuelean oil by Russian oil. So far no move has been made to act against the U. S. concerns.

Gas Price Concern. Governor Brown of California called a meeting in June because he said Californians are being forced to pay higher rates for natural gas without even a hearing by FPC. Heading the list of conferees was William R. Connole, retired FPC commissioner, who was not reappointed. In the East the coal industry fought natural gas because it sold too cheap.

Coal Advertises. The coal industry, fighting for legislation to meet oil and gas competition, took its story to the public last week in full page ads. The National Coal Policy Conference called for curbs on petroleum imports and complained of low cost natural gas to industries, calling it "dumping."

Shell Income Up. Royal Dutch/Shell earnings in the first quarter were 5½% higher than the first quarter of 1959. This was made on a total income 5% higher — an excellent record in these times of narrowing profit margin.

Time Off for Politics. Conoco employees will have time off from work without loss of pay to participate in political party activities. That was an announcement made last month by L. F. McCollum who said "Employee participation in political party activities is important personal business of the highest order." So far as anyone knows this is a first in American industry history.

Gasoline Prices Strengthen. Some restraint on refining runs enabled gasoline prices to firm up in the Mid-Continent region. Product prices had sagged below last year's levels. Crude oil prices declined slightly. Texas cut production to 8 days, equaling low record.

Forms Basic Research Unit. Esso Research & Engineering (Jersey Standard) has formed a new basic research unit that will be concerned with problems involving the various sciences and will not be engaged in short range studies. The amount of research classified as basic or fundamental amounts to 25% of total research expenditures, including the new unit.

Point of Less Return. Highway Transportation Congress estimates that the 4-cent federal and average 6-cent state taxes will increase use of compact cars. The trend toward small cars will by 1964 cause a $548 million drop in tax returns by 1964. Easy to believe.

Foreign Tax Deduction. The Senate Finance Committee has approved a bill to permit U. S. Corporation operating abroad to lump all taxes paid to foreign nations and deduct from American taxes. At present foreign taxes are deductible by country. At least it's simpler.

Varel in Algeria. The first American manufacturer has been granted a permit to set up operations in Algeria. Varel (rock, diamond, coring bits) is building a plant a Rouiba and from there will distribute in Europe and Middle East.

Predicts Price Will Hold. The Value Line Investment Survey thinks domestic crude oil price structure will hold, although a critical test lies ahead. If gasoline demand firms up well in the motoring season, products prices will rise and the heat will be off, according to Value Line.

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Memo to Management:

TO PUMP OR NOT TO PUMP *EFFICIENTLY* IS THE QUESTION

and PEPA has the answer

The question of dependable, efficient power for oil field pumping has been answered time and again with economical utility electric power. In most instances there is no substitute for the savings in maintenance, money and manpower provided through the use of purchased electric power. And this record of efficiency is not restricted to any one section of the petroleum industry. From the oil fields to the refinery it will pay you to investigate possible savings you may derive. Contact your Utility Electric Power Company for details.

A list of P.E.P.A. members will be furnished on request

PETROLEUM POWER ELECTRIC ASSOCIATION

BOX 35006, DALLAS 35, TEXAS

course of oil

We Need New Dynamism

The petroleum industry is the victim of its own success. We fired and stoked consumption of cheap energy and so efficiently filled the demand that now we are poised on the crest, waiting impatiently for a new rise. We have plenty to sell but it's the same stock. We need new goods, more style, wider virtuosity, a deeper awareness of the value of our products. We need more salesmanship.

Many are not aware of the fact, but we're getting these things. Pioneering is slow. In the early years of new ventures, the curve hugs the base before it takes off on that rise that means more customers, new areas of service and better profits.

Whoever dreamed a few years ago that we'd be liquefying gas for water transportation? Conoco pioneered this new marketing idea. It will take more years to develop it into a potent one but it's on the curve and rising.

We liked the story of Jersey Standard's salesmanship in Brazil. In 1959 a subsidiary in that country sold 300,000 kerosine-burning stoves at $1.80 each. That opened a new market! It should go well in many other countries where energy resources are small.

Service stations are taking on a fresh style, too. They are fewer and bigger and more efficient. Sun sells custom-made fuel on the spot. American Petrofina has a mobile service station—you don't even have to move your car. Phillips dealers are offering auto air conditioning on an 18-month payment plan.

The glamorous stock in our store is petrochemicals. Its possibilities reach as far as our imagination. In our predictions for the year 2059 (August 1959, issue) we published a picture of the house of the future—all plastic. This may come faster than you think. In Humble's new 44-story building at Houston, Texas, a cushion and water protector of butyl rubber was spread between concrete slabs for the foundation, a unique use for this petrochemical. When plastics can compete in building materials, we'll have a market that will make that sales curve leap.

The fuel cell is on its way, too. It converts gas into electricity right outside your door and promises to be one of the greatest breakthroughs of our research.

And speaking of research, let's don't forget it. We're spending more than ever in our history on research. In turn, it's bringing us new sparks to light a new dynamism that will reach from the producer to the mobile service station man.

Our title is not quite accurate. We HAVE a resurgent dynamism. We have a fresh approach. We're searching out new products and using super-salesmanship to sell old ones.

When we started writing this we had "cut costs" and "watch your politics" in the outline. But a dynamic industry burns away useless expenditures and it need never be defensive in public affairs.

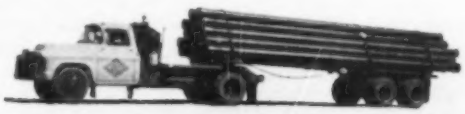
What we need most is a realization of our great future.

Ernestine Adams

Congrats and $25 for this quip to J. P. DENNY, Phillips Petroleum Company, Box 1351, Odessa, Texas

Oil and gas men are quick to say that Lone Star products are "tough, top quality and delivered fast". Quick supply, and superior steel are among the reasons more and more have switched to Lone Star API casing, tubing and line pipe.

Exacting quality control combined with years-ahead manufacturing techniques today . . . are your guarantee of API standards in Lone Star pipe. And remember, delivery in the field is a matter of hours.



Neighbor, wherever you are, specify Lone Star and we both get a good deal.

Lone Star STEEL COMPANY

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petroleum profile

IN 1921 THE CATTLE BUSINESS was in a bad shape. A ranchman down in Palo Pinto County, Texas, had a son in Texas University and the son, Morgan, quit school and hunted a job. He found one at the Tulsa (Oklahoma) Spavinaw water project and made a reputation as an engineer.

This incident illustrates two characteristics that make Morgan J. (for Jones) Davis an able and forceful president of Humble Oil & Refining Company, Houston, Texas.

He grew up in a pretty affluent family but he wasted no time when affluence took a temporary down curve. He had bent all his efforts to gain an education as a geologist, yet he took a job as an engineer and was so competent he progressed to assistant superintendent in three years. He also went from $100 a month to $250 a month salary so the promotions weren't honorary. Not only was his work well done but he successfully courted Veta Clare Moore, whom he married in 1926.

In 1924 he went back to the University of Texas and the following year received his degree in geology.

He'd wanted to be a geologist since he'd received a book

MORGAN J. DAVIS

President — Humble Oil and Refining Company

on rocks and fossils for his ninth birthday. It took him a long time to get that degree but he had some very special courses —like the detour into practical engineering.

When young Morgan completed high school in Fort Worth at 16, his folks thought him too young for college. He'd worked on his father's ranch during summer vacations —now he spent a year being a full-fledged ranchhand.

Next year the 17-year-old entered Texas Christian University where he studied two years and then transferred to the University of Texas because it offered more in his chosen major. At Texas University he met a man whose steps he followed for many years, L. T. Barrow, a student instructor in geology, who later went with Humble.

After being a cowboy and an engineer, the new graduate now became a geologist. Barrow helped arrange a job with Humble in this June of 1925 and Davis went to work in the old Cisco Division; later was sent to Roswell, New Mexico, to head the office there.

In the next four years he became an authority on New Mexico and West Texas and was one of the first to appreciate the bright oil future of the area. But this rather rugged life grew tame and Davis took on the more exciting venture of geologist for Nederlandsche Koloniale Petroleum Maatschappij in Java. By this time he had married his Oklahoma sweetheart and Morgan, Jr., had arrived, so it was a family of three that journeyed to the Far East. Later Davis became resident geologist in Sumatra and spent some happy years in the tropics.

Of course, restlessness set in again and the Davis family returned to the U. S. They had been gone four years and eight months. In the meantime Barrow had become chief geologist of Humble and he readily hired Davis as district geologist at Roswell. From then on Davis climbed a promotion ladder of almost even steps—division geologist for the Gulf Coast, acting chief geologist, and chief geologist (1941). This had been his ambition and he had reached it. But this geologist wasn't inclined to let fate have a free hand with his destiny. He began searching for new frontiers. In 1946 the geologic, lease, and scouting departments became the Exploration Department and Davis was made manager over this wider field.

When Harry C. Wiess, Humble president and one of the founders, died in 1948, Hines H. Baker became president and chief executive and L. T. Barrow moved up to chairman of the board. At this time Davis was elected to succeed Barrow as director in charge of exploration. In 1951 Davis became vice president, then executive vice president, and in 1957 was elected president.

So in the last 12 years, the man who pursued his profession so singlemindedly all his life, has become — not only a geologist but an executive. He says he isn't a typical geologist. And why?

"Because a real geologist is more scholarly."

The term may not quite fit Mr. Davis because it seems opposed to action but the president of Humble has an incisive mind and keen judgment.

Respect for his profession is reflected by his sons' choice of a career. Morgan, Jr., who is married and has two children, is a geologist with International Petroleum Company in Talara, Peru. James, the other child, received his degree in geology last year from Washington and Lee.

Mr. Davis is chairman of the Advisory Council of the Geology Foundation at University of Texas and is on a committee for Harvard's Division of Geological Sciences.

If you knew nothing about him, you'd find it hard to place Mr. Davis as president of one of the largest organizations in the petroleum industry. Tall with quick, easy movements, he gives one a David Nivenish impression until he speaks. Then the scientist-executive emerges and you meet an earnest man who is widely knowledgeable and carries his responsibilities confidently.

"What one trait does a successful oil man need?" We ask him.

"I can't settle on one—two stand out," Davis said. "The first is honesty. There is a great deal of business—big business—in the oil industry that is carried on by word of mouth.

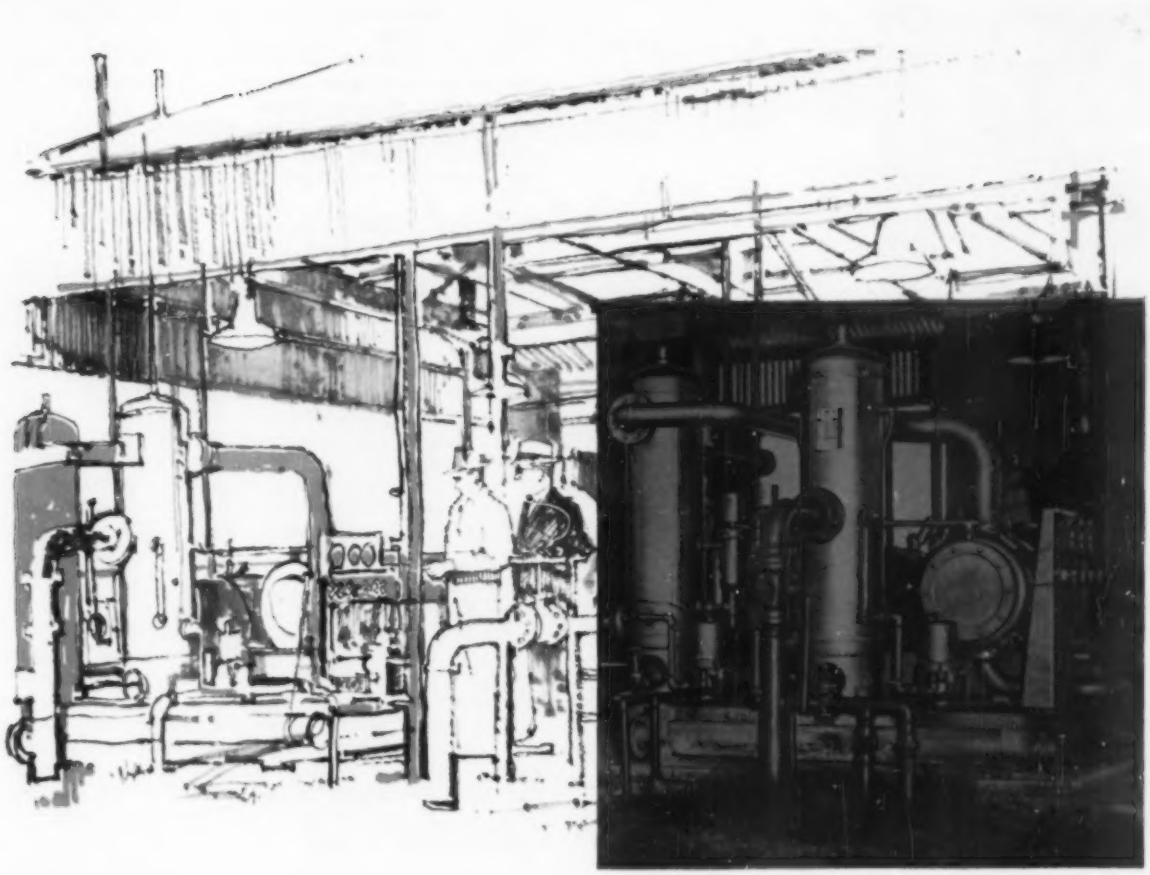
"The other necessary characteristic is optimism. You're going to fall by the wayside without a cheerful faith in good fortune."

And is he optimistic now?

"For long range, yes. There is nothing particularly optimistic about the near term."

Questioned about when things would change, he said, "In the next two to four years if we have good management, not too much government, and some good luck in the meantime."

The cowboy-engineer-geologist-manager is probably a good prophet, too.



Selling gas? "Oilwell" Compressors boost efficiency...too!

At this station—owned and operated by Robert A. Cargill of Longview, Texas—two "Oilwell" DGE-150A Compressors are in gas booster service. These units take gas from wells at 25 psig and deliver it into the sales line at 400 psig. Each unit handles 1,020,000 standard cubic feet per day. These compressors operate continuously with a minimum of supervision and maintenance.

You can accomplish a wide variety of gas-handling jobs with "Oilwell" Compressors. They can be furnished from 25 to 500 hp for single or multi-stage compression. For perfect alignment and compact installation, a single structural steel skid carries compressors, engine, gas scrubbers, mist extractor units and controls.

For detailed technical information about the advantages of an "Oilwell" Compressor on your next gas-handling problem, visit your "Oilwell" store or write to Compressor Department, Oil Well Supply, Dallas 21, Texas.

USS and "Oilwell" are registered trademarks

USS Oil Well Supply
Division of
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Executive Offices: Dallas, Texas
Export Offices: 30 Rockefeller Plaza, New York 20, N.Y.

the conference table

Check Your Emergency People

Through the National Petroleum Council, the oil industry is already organized for emergency, which is as it should be. As Walter S. Hallanan, chairman of the committee, says "Despite the development of missiles and nuclear bombs, oil continues to be the first line of national defense."

If you don't know your committee members, you can look them up in the May, 1959 issue of THE PETROLEUM ENGINEER, page A-36. The emergency oil and gas committee is part of the National Petroleum Council. Besides Hallanan, the vice chairman is R. G. Follis; assistants to the chairman are J. Ed Warren and Robert E. Wilson and the secretary is James V. Brown. Government co-chairman is Frederick S. Lott.

"Growth is the only evidence of life."
— John Henry Newman.

Executive Development Aids

Most petroleum management people know about the small booklets put out by the Executive Development Press on management problems and what to do about them. One of our favorites is an old one called "Obvious Adams, The Story of a Successful Businessman" written by Robert Rawls. This is a reprint of an article carried 44 years ago in the Saturday Evening Post and now published with notes written recently. It covers five creative approaches to the obvious.

The *first test* of obviousness was borrowed from Kettering of General Motors, who placed it on the wall of the GM Research building: *This problem when solved will be simple.*

The *second test* of obviousness is: *"Does it check with human nature?* That is, will it be pretty well understood by family, neighbors and fellow workers?

The *third test* is: *Put it on paper.* Write it out as though you were explaining it to a child.

The *fourth test* is: *Does it explode in people's minds?* When they have heard it do people say "Now why didn't we think of that before?"

The *fifth test* of obviousness is: *Is the time right?* Sometimes the time has passed definitely or its timeliness may be ahead, so you must be patient.

"Obvious Adams" as well as others of the Executive Development, Littleton, New Hampshire, series is sold in single copies for $1 and for less in quantity.

Oil and Gas Center Established

Southern Methodist University's Southwestern Legal Foundation has set up a new organization for the petroleum industry. It is called "International Oil and Gas Educational Center."

First, a 14-man advisory board was selected, of which George Ray, Jr., of Aramco is chairman; vice chairmen are John G. Pew, Sun Oil, and Gordon Simpson, General American; secretary is Charles Wallace, Mobil Oil. The advisory board will make recommendations regarding the educational needs of the oil industry and the foundation will arrange for the educational programs. Experience with the oil and gas legal seminar each year has made the Foundation realize the need for further education for adults in the petroleum industry.

New School Started

IBM has established a Systems Research Institute in New York City which is the first of its kind in the computer industry. A graduate level school, it will train people to find computer system solutions to complex business and scientific problems. The curriculum will include such subjects as case studies in systems-design, workshops in systems planning, advanced programming, and business simulation techniques. IBM expects to train up to 400 people a year.

French Interests Detailed

Dr. Perrodon, author of the impressive study of the French Algeria/Sahara, points out that the ownership of Compagnie de Recherche et d'Exploitation des Pétroles and Sahara (CREPS) is held 51 percent by Régie Autonome de Pétroles (RAP), a French State company, and 35 percent by Royal Dutch/Shell. RAP also provides the engineers and technicians for CREPS.

In our list of companies in Sahara we indicated only percentage of ownership in various firms held by outsiders and made no effort to show the numerous French interests in each company. We felt that French ownership was evident in virtually all the organizations operating in the French/Sahara.

Would You Swap With USSR?

Congressman Bruce Alger (Republican, Texas) gave his constituents this to think about:

"What if we could swap positions with the Russians? If you could trade places, and problems, with them tomorrow, both nations would still have operational missiles with lethal destructive capability, but *you* would also face a nuclear bomber force at least four times the size of yours, poised at innumerable nearby bases in every direction from you, and against which you have virtually no proved defenses. There would be aircraft carriers and strong naval forces cruising one hundred miles off your coast, capable of launching nuclear bombers and missiles. Nuclear submarines would lie undetected within missile range of every one of your major cities. And there you would sit, with no comparable weaponry.

"If we traded places with Russia we'd find ourselves producing only ⅖ as much steel, ⅓ the hydro-electric power, ⅓ as much oil, and ½ as much aluminum; 10 percent as

New Peerless Gas Cleaner development provides cleaner gas at less cost

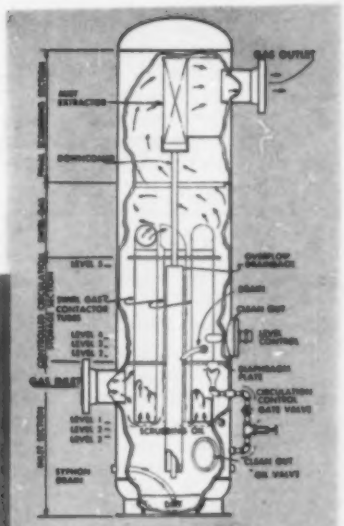
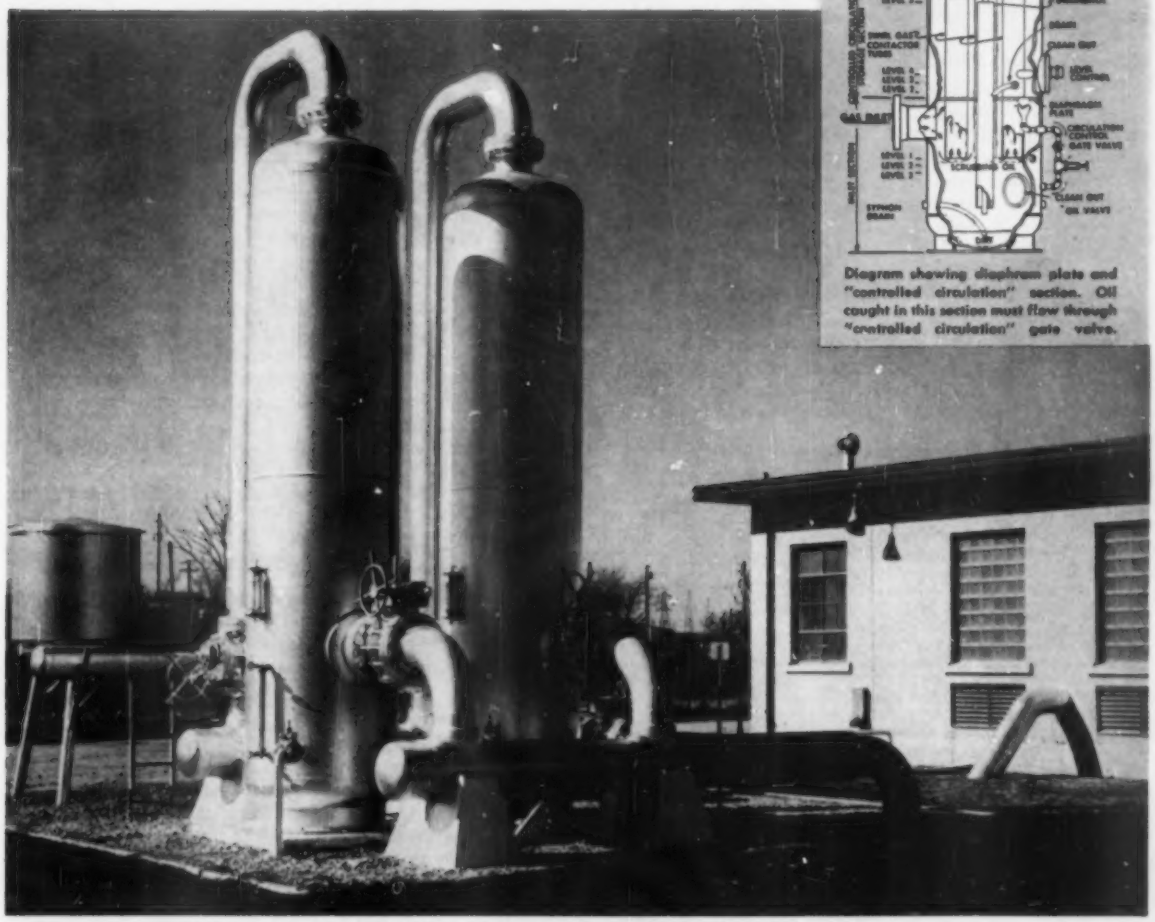


Diagram showing diaphram plate and "controlled circulation" section. Oil caught in this section must flow through "controlled circulation" gate valve.



More efficient liquid and dust removal is provided with Peerless "Controlled Circulation" Vertical Swirl-Gas Cleaner

With given gate valve setting, circulation of scrubbing liquid varies within narrow range even with widely varying gas flows . . . thus greatly reducing scrubbing oil loss. Scrubber will remove small quantities of dry solids or separate large quantities of liquid equally well with no adjustments required. In addition there are higher gas capacities because of limited mist extractor loading, less entrainment at gas exit end of contractor tubes, and use of larger mist extractor.

For details, Write for Peerless Bulletin 6-193.

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much natural gas, ⅓ as much copper, and only 5 percent as many electric motors.

"To get in Russia's shape, we would have to abandon 14 out of every 15 miles of highway, destroy 19 out of every 20 autos and trucks, scrap two out of every three miles of railroad track and 60 percent of our freight cars, and sink eight out of every nine merchant ships. And we think *we've* got problems!

"If we traded places with Russia, our only gain would be a rocket on the moon! Oh yes . . . it was free enterprise and individual freedom that produced our present armed might, and the economic strength to support it."

How to Measure Business

One of the peculiar things of this age of mixed-up philosophy is that we avoid the term "profits" as if it were a dirty word. In the socialist's scheme of things you run a business for the love of it and you divide your earnings because you want to share (if there are any earnings).

So we were interested in the article "Profits . . . They Measure Your Progress," an article in The Standard OILER for April, 1960. The article points out that profits are not income as some people think and that it's partly from profits that money is found to expand and improve and to meet competition.

Then the article gives its statement as applied to each employee. We think it's interesting enough that it might be useful for other companies. Here's how the Socal statement came out:

If you were in business for yourself

If you owned a business equal to one employee's portion of Standard of California it would have a book value of . . . *(Socal's cash, plant, and equipment and other assets less current liabilities and reserves ÷ average number of employees)*	$58,200
Assuming you ran your business in 1959 as Socal did: You sold products and services amounting to	$46,700
Dividends from affiliated companies and other miscellaneous income brought in	3,000
Making total income for the year	$49,700
However, during the year, you bought crude oil, processed it, paid operating, marketing, and administrative expenses including salaries, wages, benefits, and taxes. All told, this cost you	$43,100
Making your net profit	$6,600
Assuming you were set up in business as Socal is, with all the assets of the company owned by stockholders, you would have paid them a return on their investment of $58,200. Paying them dividends at the same rate as Socal did last year amounted to	$3,300
This left you with	$3,300

What to do with this $3300? *It's an important decision, a far-reaching one. If you want to keep earning a profit, if you want to be able to keep ahead of your increasing competition, your best course is the same as the one Socal took . . . reinvest in your company for future growth. The decision is yours alone to make.*

What OCAW Wants

A conference of Southwestern representatives of the Oil, Chemical & Atomic Workers International Union recommends that future union efforts be directed toward "more secure" work contracts and a general wage increase.

OCAW President O. A. Knight of Denver, Colorado, said the recommendations will be given consideration by the union's national bargaining committee. Recommendations are:

1. Elimination of the "job security threat" resulting from "spot contracting" by oil firms for refinery maintenance work.
2. Attainment of a "substantial general wage increase" with consideration given to applying part of the money to fringe benefits.
3. Payment by oil firms of all fringe benefit costs, or alternatively, that benefits be paid from trust funds administered jointly by union and management.
4. Reduction of overtime to obtain a "standby shorter work week" clause in line with pre-World War II policies.

10 Steps in Public Relations

Here are 10 simple steps to a successful public relations program. They are worth trying.

1. Employ a person who is skilled in the field of public relations.
2. Make maximum use of the public relations director in a counseling capacity.
3. Select a committee of executives to work with the public relations director.
4. Determine the company policies.
5. Determine the company publics.
6. Analyse the attitude of the various publics toward the company and determine the best way to reach them.
7. Study the needs of the company.
8. Educate the executive staff and employees of the need for good public relations and their part in the program.
9. Study each policy decision and its effect on public relations.
10. Provide adequate funds and personnel to do the job.

Texas Industry

Cancer-Producing Oils

A $42,205 grant has been made to The Chicago Medical School by the U. S. Public Health Service, for the study of possible cancer-producing substances in oils derived from petroleum and used medicinally.

Booklet Worth Reading

An excellent monograph has been written by Lloyd F. Thanhouser, vice president and general counsel, Conoco, on "Government Regulation of Private Business." It is published by Alexander Hamilton Institute, 71 West 23rd Street, New York 10, in its Modern Business Lectures Series.

We recommend that the booklet be read for better understanding of government power in business and how it has grown. Most people in our industry have some knowledge of rules governing oil and gas operations. This will put these specific cases in a broader background.

Our Creed

From Leonard Refineries 1959 Annual Report

Leonard Refineries, Inc. recognizes the American Corporation as the fourth organization of society to achieve the status of a perpetual institution, the others being the Church, the State, and the University.

We believe that a perpetual institution has and must accept inherent responsibilities to all people.

We believe that the Good Citizenship responsibilities of the American Corporation include developing and maintaining a climate in which there can exist:

A constant search for ways to encourage greater creative knowledge and creative manpower;

A free and competitive economy in which all people may share, as workers at fair wages, as investors at a fair rate of return, and as customers paying fair prices for quality products.

Good Wells Make Good News

July 1960

SECONDARY RECOVERY – water flooding – water disposal–gas injection – pressure maintenance . . . all these activities are becoming more important every day to the profitable production of oil and gas. Here are four recent examples showing how Dowell can help operators who are engaged in these activities.

- **Brazoria County, Texas Gulf Coast** (Water disposal well) This well had been perforated conventionally into the Miocene sand between 2205 and 2214 feet. Before treatment, it was taking 2400 bwpd at 540 psi. Operator wanted to reduce injection pressure, and Dowell recommended Abrasijet*, Dowell's abrasive jetting service. Since 24 perforations were desired, Dowell devised a closed system to use the same sand and water repeatedly. 6500 pounds of sand in water were used to perforate 12 levels (2 holes each) in about 2 hours pumping time. Pumping rate averaged 3 bpm. Three months after treatment, well was taking 2200 bwpd at only 150 psi.

- **Franklin County, Illinois** (Waterflood injection well) This open hole was in a very thin (three foot) section of the Tar Springs sand at about 2060 feet. Dowell used Abrasijet followed by acid. 10,000 pounds sand in water were used with a Dowell agent–Slick Water–added to reduce friction pressure. Total jetting time was one hour and 20 minutes for each one-foot level. Jetting pressure was 2800 psi. Zone was then acidized using 833 gallons Dowell acid. Before treatment, well took only 20 bwpd at 1000 psi line pressure. After treatment, it would take 88 bwpd at 950 psi.

- **St. Landry Parish, Louisiana** (Gas injection well) This well had been recompleted into the lower Miocene sand between 8444 and 8484 feet. Before treatment, well would not take gas at 4700 psi. Dowell acidized using 6000 gallons Mud Acid with a silicate control agent added. 250 gallons of a Dowell temporary plugging agent were injected about one quarter of the way through the treatment to divert acid to tighter sections of zone. After treatment well was taking 25 mmcfd at 4700 psi.

- **Ward County, West Texas** (Water disposal well) This old oil well was converted to water disposal by setting a blank liner across the abandoned pay—11,927 to 12,207 feet—and deepening to 12,403 feet. The new open-hole Devonian section was treated with 10,000 gallons Dowell regular acid injected down 2⅜-inch drill pipe at 7.5 bpm and 4500 psi. Gravity flow injection tests, made both before and after treatment, showed an injection rate increase from 28 to 660 bwph.

Why not find out all the ways Dowell can help you make your operations more profitable. For service or detailed information, dial Dowell. Dowell services and products are available from more than 150 offices and stations in the U. S., Canada, Venezuela, Argentina and Germany. Dowell, Tulsa 1, Oklahoma.

*DOWELL TRADEMARK

Services for the oil industry

DOWELL

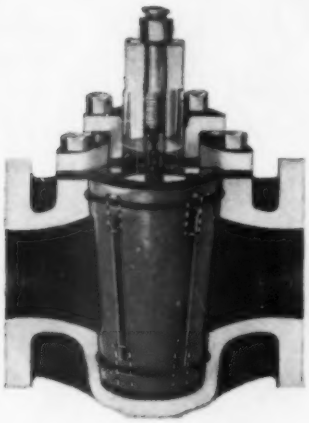
DIVISION OF THE DOW CHEMICAL COMPANY

the idea:

Simplicity Is Basic To Efficiency and Economy

One of the world's first valves, plug cocks invented by the Chinese centuries ago, had only one moving part—the plug. Even the earliest craftsman recognized the fact that simplicity of design almost always means a device that works better, lasts longer and costs less to use.

the application:



How It Helps Give You A Better Valve

In the modern Rockwell-Nordstrom lubricated plug valve there are only three rugged, basic parts . . . plug, body and cover. The plug is the only moving part. Compared to other valves, nothing could be simpler or more efficient. Yet the many advantages of simplicity are actually multiplied by *lubrication* in these valves. Pressurized lubrication jacks the plug, keeping it free for instant ¼-turn operation. It also forms an instantly replaceable, impenetrable seal against leakage, and prevents metal-to-metal wear.

the benefits:

Longer Valve Life At Lower Cost . . . Leak-proof Sealing . . . Reduced Down Time . . . Completely Protected Seating

The 6 million Rockwell-Nordstrom lubricated plug valves now used in a wide variety of industries are translating these benefits into dollars and cents savings day after day. Rockwell-Nordstrom is the most complete line of lubricated plug valves (sizes from ½" to 36"; pressures to 15,000 lb), lubricants and operating accessories. For *practical* help in solving your flow control problems, see your supplier or write: Rockwell Manufacturing Company, Dept. 94-G, Pittsburgh 8, Pa. Canadian Valve Licensee: Peacock Brothers Limited. If you live outside the U. S. or Canada, write: Rockwell International, S.A., Geneva, Switzerland.

Lubrication Makes The Difference

ROCKWELL-Nordstrom VALVES

another fine product by

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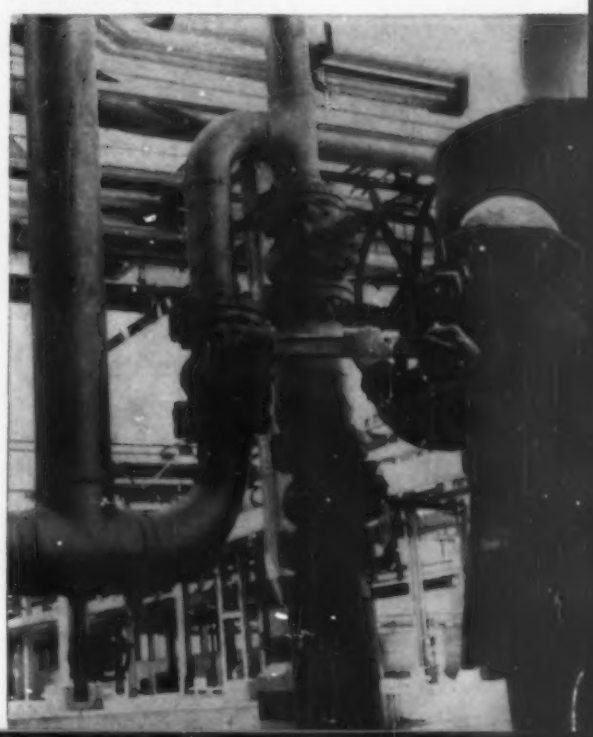
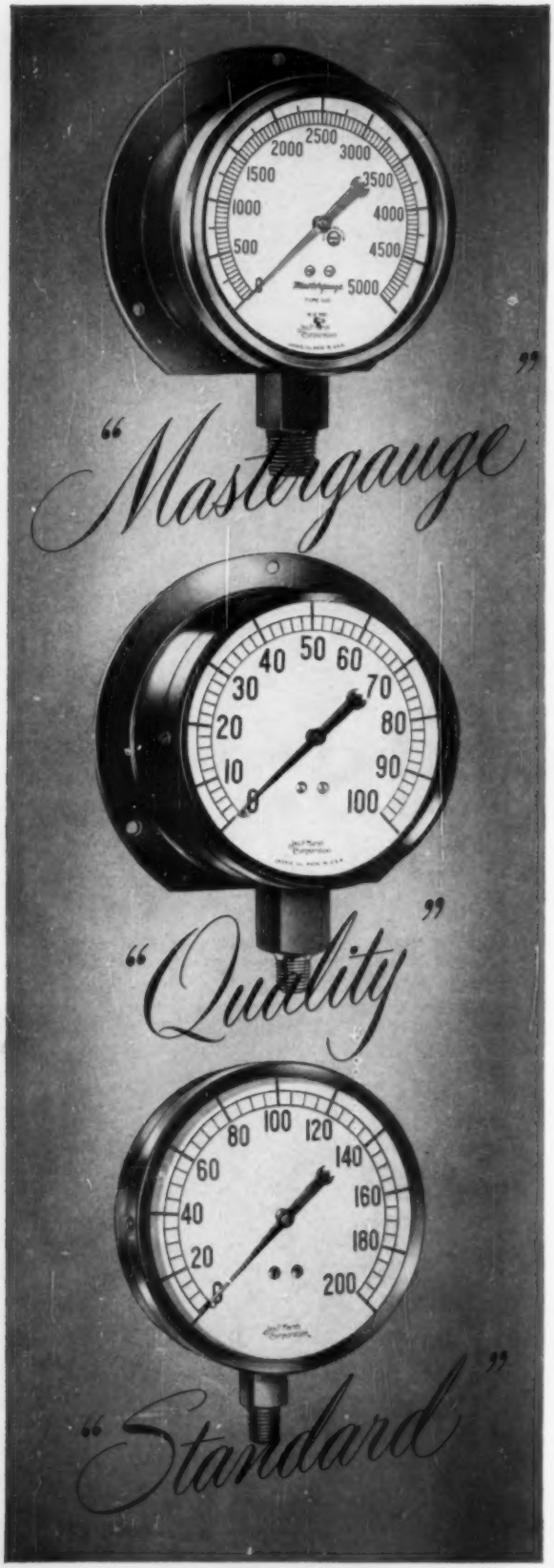
For every refining valve need (Toluene plant service below) there is a Rockwell-Nordstrom valve to insure positive, leak-proof control.





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THE "QUALITY" GROUP...also for tough conditions, but less severe than the conditions served by the "Mastergauge" Group.

THE "STANDARD" GROUP...for the general run of pressure gauge services.

While these three brackets run a wide gamut of prices, the difference between them is not so much a matter of *grade* as a matter of *kind* and *purpose*. All gauges in all groups reflect Marsh precision and quality. Collectively they cover practically every conceivable gauge requirement.

The answer is in the catalog...but if you have a special problem let our engineering department work with you to select the most efficient, most economical solution to your problem.

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D6B MOVES EARTH FASTER—preferred by oil company

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"It's the best!" That's how owner Willie M. Mitchell described his new Cat D6B Tractor at a site preparation job 5 miles east of Perrin, Texas. "I'm moving dirt faster and easier than with my previous D6 and maintenance time is cut in half—the oil company I do work for wants Cat equipment on the job. They know they are getting more work for the hours they pay for."

Working in clay and packed drilling mud in wet weather, Mr. Mitchell dozes about 100 yards an hour in 150-foot passes. In a 10-hour day, he dozes or moves about 1000 yards. He finds the D6B with an 8-foot blade ideal for this kind of work. The short straight blade combines productive capacity with narrow width. No highway permits are required to move the machine from job to job.

Willie M. Mitchell has been operating tractors for the past 15 years and he knows what he is talking about when he states that the D6 "maneuvers well, has plenty of power, and visibility is good."

Your Caterpillar Dealer can prove to you right on your job how the new D6 steps up production. Call him today.

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New Operator Convenience — All new cockpit has co-ordinated controls that make operation nearly effortless.

PLUS Timesaving Maintenance Features — The exclusive oil clutch gives up to 2000 hours of adjustment-free service. Lifetime lubricated track rollers with exclusive floating ring seals never need servicing during life of roller. Dry-type air cleaner removes 99.8% of the dirt even in the dustiest conditions, is serviced in just 5 minutes. Hydraulic track adjusters (optional).

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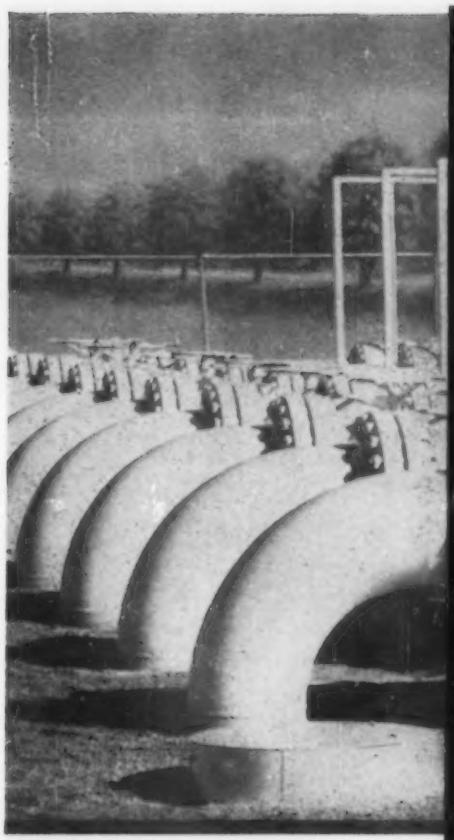

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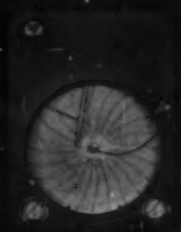

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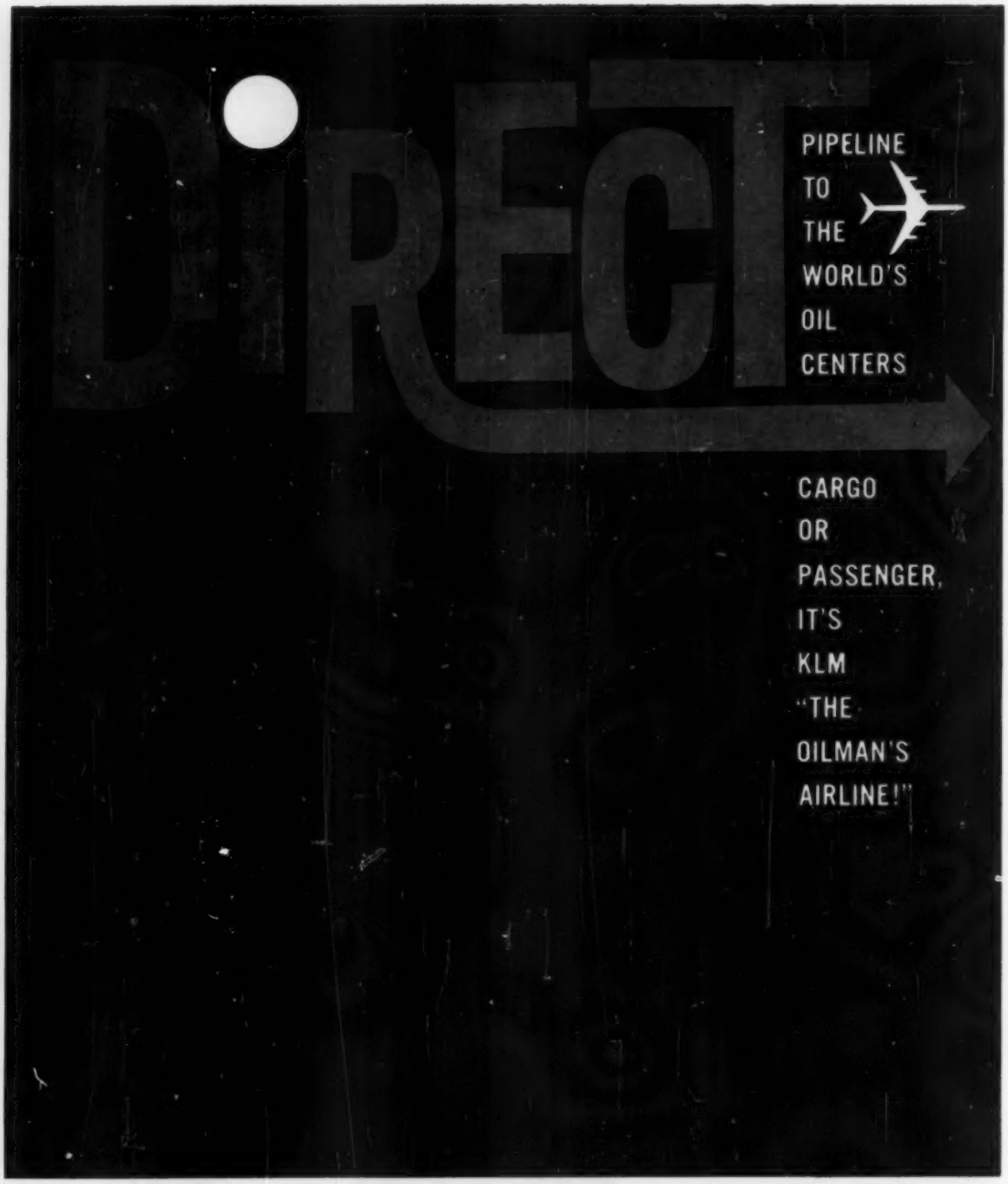

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When Will Industry Learn to Manage Surplus?

Soon, says this oil executive . . . too much is at stake to allow international oil situation to deteriorate

Thornton F. Bradshaw

WHAT HAS HAPPENED to oil stocks? Three things, I think —

First — The current surplus situation.
Second — some loss of confidence in oil managements.
Third — The emergence of newer glamour industries — space, electronics, chemicals.

The current surplus situation is very real. The domestic surplus might be something like 30 percent. Abroad, Venezuela's shut-in capacity is probably somewhat similar. The Middle East is, of course, producing an extremely small proportion of its known reserves.

Hovering over the world's known reserves is the specter of new discoveries. Libya with its remarkable Zelten wells and its ready access to the European market. French Sahara with its markets by fiat in the French nations.

What kind of talk is this? The specter of new discoveries! Look forward with fear to increasing reserves! An exploration man I know has said that, "In years gone by we opened a case of champagne when we hit a new field. Now when a new well comes in, I am afraid to cable the home office."

What kind of an Alice in Wonderland world is this when we look upon an abundance of a basic energy supply with misgivings? Are the energy needs of this country sated? Not in my house they are not. Are the energy needs of the world sated? In Europe where the per capita consumption is about 33 percent of ours? In Asia and Africa where the per capita consumption is about 5 percent of ours?

The oil surplus is real and it must enter into your thinking and into mine, but in a broader sense the problem is not do we have too much oil, but do we have enough to meet the tremendously expanding needs of the world? The immediate problem is one of management of our riches, and I would much rather be faced with that problem than with the problem of creating riches out of poverty.

The first point I want to make, therefore, is that the problem is not the existence of surplus oil. I think we can offer up a short prayer of thanksgiving that we have enough oil to meet the needs of the world, and then move on to deal with the real problem, and that is how to manage the surplus.

If managing the surplus is the problem, the key question is — When will the industry learn how to manage this new kind of oil industry?

And here, perhaps, I am moving into the second area of what I conceive to be your concern over the future of the oil industry — some loss of confidence in the management of the oil industry. I am sure many of you agree with Sterling Popple who said last fall: "It is not 1959 that troubles investors in the petroleum industry. That has already been written off. What does trouble them is that the industry, because of its own lack of self-control, converted what should have been a good year into a mediocre one. If that occurred under favorable circumstances, what is there to insure that the next year won't be spoiled in the same manner?"

The immediate past history would certainly indicate that oil managements have not yet learned how to live in this new world of surplus. But I ask you to consider two things: First, the rapidity with which this surplus situation was thrust upon us; and second, the very brief period which oil managements have had to readjust the thinking and actions of a lifetime.

You are all well aware of the build-up of events which led to the severe supply-demand dislocation in 1957. During the post-war years the domestic oil industry enjoyed a growth rate of more than 5 percent a year and all segments of the industry expanded capacity significantly.

Two events triggered off the explosion of 1957: The unexpectedly rapid ending of the Suez Crisis; and the 1957-58 general economy recession. Stocks of major products soared in the fall of 1957 to all-time highs and product prices collapsed. The Gulf Coast refiner's margin dropped from its peak of $1.08 in April 1957 to a low of 41 cents exactly a year later.

The rapidity with which these events occurred left very little time for oil managements to learn how to manage in a world of surplus.

We can call upon past history to gain some insight into the possibilities for effective management of the surplus. Throughout much of the 1920's, a relative balance of power existed among the seven oil companies which produced most of the world's oil. In 1926, however, the balance of power began to deteriorate. For a period of time, the situation began to look surprisingly like today's picture.

In 1928 a conference of major oil companies was held at Achnacarry Castle in Britain, the home of Sir Henri Deterding, head of Shell. The result of this meeting was the Achnacarry Agreement, or the "As-Is" Agreement, which has been described as "the most effective experiment in economic world government thus far achieved in the twentieth century."

The Agreement contained these principles:

1. Each company was to retain the percentage of the market enjoyed at the time by the company.
2. Each producing area was to have the advantage arising from geographical position — that is, should sell in the nearest market.
3. Supplies for each market should be drawn from the nearest producing area.
4. Surplus production in any producing area was not to be "dumped" in other areas to the disturbance of the price structure.
5. No measures were to be taken which would materially increase the cost of producing oil.

Did the agreement work? Adolf Berle in his remarkable book, "The 20th Century Capitalist Revolution," said:

"The fact was that from 1928 to 1939, the period in which the Achnacarry Agreement and its successor agreements governed the petroleum supply of the world, there was peace and there was production, and there was distribution and there was a stable and reasonably acceptable price. By absolute standards, the Agreement has to be accounted a success . . . As an experiment in world economic government, the companies cannot on this record be accused of failure."

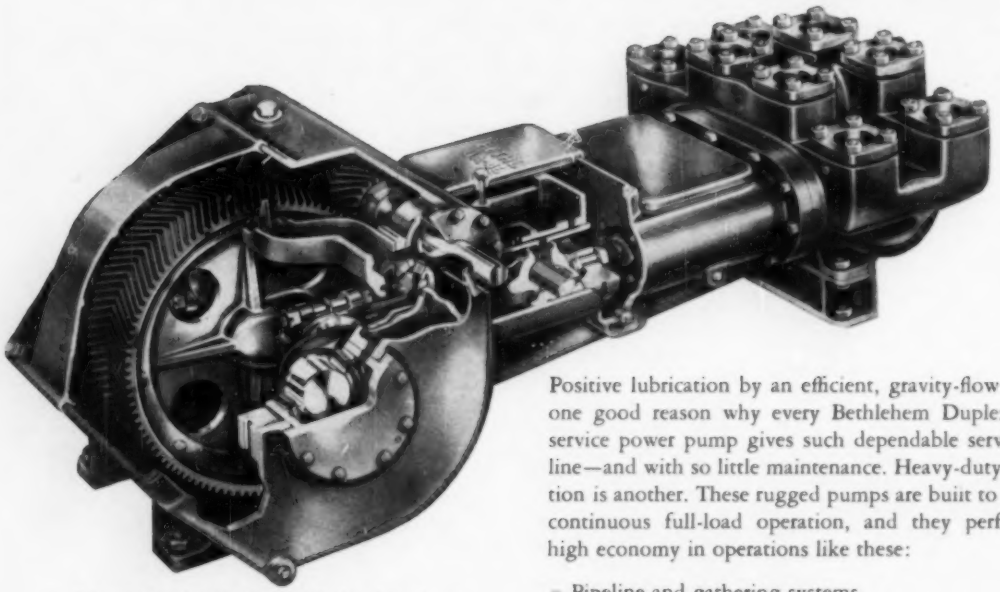
Does this mean that management of the surplus can now be accomplished

---

EDITOR'S NOTE: Mr. Bradshaw, vice president and general manager of Finance and Accounting, The Atlantic Refining Company, spoke May 17, 1960, to National Federation of Financial Analysts. This is a condensed version.

The Bethlehem Duplex

Keeps Oil On The Move



Cut-away drawing of the U-510 Duplex shows how lubricating oil, continuously collected from the gear rim, flows through the main and pinion bearings and into the oil chest, from where it is directed to the crossheads and to the crosshead-pin and connecting-rod bearings.

Positive lubrication by an efficient, gravity-flow system is one good reason why every Bethlehem Duplex general-service power pump gives such dependable service in the line—and with so little maintenance. Heavy-duty construction is another. These rugged pumps are built to run under continuous full-load operation, and they perform with high economy in operations like these:

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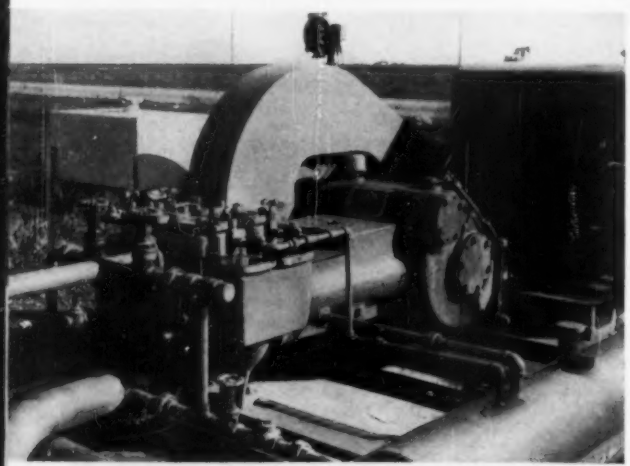

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by agreement among a few large companies? No. Times have changed. Three factors are all important:

1. American companies now account for substantially more Eastern Hemisphere oil than they did 20 to 30 years ago. It would, of course, be impossible for American companies to participate in such an agreement today. Even under the Achnacarry Agreement, the domestic market and import trade of the United States were excepted.

2. Some of today's existing and potential surplus is in the hands of a large number of new producing companies. These companies are under severe pressure to push production and recover their investments. World oil is no longer exclusively in strong hands.

3. Oil has become a primary national resource — and here the emphasis is on the word "national." This factor consists in reality of two parts — first, the growth of national entities as major producers — ENI, NIOC, the maze of corporations controlled by the French Government, the new Venezuelan National Oil Company, the YPF in Argentina. The second part consists of the realization by those countries which have vast deposits of oil of their dependence upon oil to achieve economic growth within their countries.

This third factor, in my opinion, points to the most likely direction in which a balance of power — and hence control of the surplus — may be achieved. You are well aware of international oil proration proposals. I suppose most oil men regard the possibility of successful international prorationing as being slim. They point to the rivalry of the Arab and non-Arab Middle Eastern countries . . . to the necessity for developing the French controlled Sahara production, and the pressure for developing the new Libyan fields. Finally, they point to the possibility of creating a vacuum into which Russia may be all too willing to pour oil to create troubled waters.

A second possibility for control of the surplus is an informal cooperation between the larger international companies and the oil-producing countries.

I cannot forecast the form control will take; I am convinced that control of the surplus of some sort or another will become effective and in the relatively near future. Too much is at stake to allow the international oil situation to deteriorate into chaos.

I have concentrated on the foreign picture because it is here that the illusion of waiting out the surplus is most clear. For the domestic situation we have the basic tools at hand to manage effectively during the period of surplus — state prorationing and the mandatory import quota system.

Two things are needed before these tools are sharp enough to do the job. First, states other than Texas will have to bear their share of the burden of prorationing and, second, oil company managements will have to learn how to help the states use the prorationing tool more effectively.

Now what has this somewhat fanciful excursion into the realm of the international economic balance of power got to do with the future of oil company profits? I have tried to make these points:

1. The oil surplus is a blessing, not a scourge.
2. Too many people believe that oil profits will return to adequate levels only when the surplus has disappeared. The oil surplus is not going to disappear for many years, and I personally hope it never does.
3. A return to an adequate level of profits will occur when oil managements and governments learn how to manage the surplus effectively.
4. Because of the emergence of an intensified national interest in oil, I believe an effective international balancing machinery will be created in some form in the relatively near future.
5. Because of lessons learned in the immediate past, I believe both managements and states will use the present domestic tools effectively in the near future. ★ ★ ★

Have You a Security Program?

Jersey Standard has set up emergency headquarters . . . Has regular drills . . . Three cadres of executives . . . It's too late to plan when disaster befalls

ONCE A YEAR, the headquarters of Esso Standard Oil Company shifts for a day to a rural scene 30 miles from New York, according to Kenneth E. Yandell, security coordinator of the firm.

This shift is a drill, to make sure that Esso's defense plans will work in case of threatened enemy attack. The alternate headquarters is bossed by executives who live nearby, so that men who can reach the site will be able to carry on the company's business. Higher executives who live farther away can't be counted upon to reach the headquarters through the chaos that would follow an attack.

Fifty bedrooms and baths in the converted 60-acre fenced rest home could accommodate 65 persons. Today, three persons staff the lonely house, keeping up-to-date the microfilmed records stored in the underground vault.

But Esso has found another use for the headquarters, Mr. Yandell reported. Staff meetings are held there, saving the cost of hotel accommodations and removing the distractions that sometimes prevent maximum productivity at in-city meetings.

When Jersey Standard undertook a security program, its goal was to set up alternate headquarters outside New York and to draw up a master plan to continue the company's vital operation in event of enemy attack.

At the outset, administrative control was made a responsibility of top management, thus lending the program status, urgency and enthusiasm. A 12-man security committee was ultimately formed to establish a comprehensive program and later to administer it.

Among the committee's recommendations was a five-point program which became the nucleus of the Jersey security program. They called for:

1. Remote storage of all vital corporate records.
2. Designation of alternate company headquarters for emergency use.
3. Preparation of management succession plans.
4. Amendment of corporate bylaws, where necessary, to facilitate emergency action.
5. Protection of vital production, research and operating facilities against sabotage and espionage.

Now the headquarters is the hub of an emergency communications network, including a three-position telephone switchboard connected directly to other Esso facilities and to Washington; teletypes, and two-way radio circuits.

Three cadres of executives and staff are assigned to emergency jobs, and should world tensions worsen sharply they would staff the headquarters on a rotating basis for one week at a time.

Another important facet of Jersey Standard's security program is its plan to regroup employees after an attack on New York. Throughout the metropolitan area the company has established 15 reporting centers where employees may report their availability for duty. The reporting centers, tied into the emergency headquarters' communications networks, are located in nine company installations and six employee homes. ★ ★ ★

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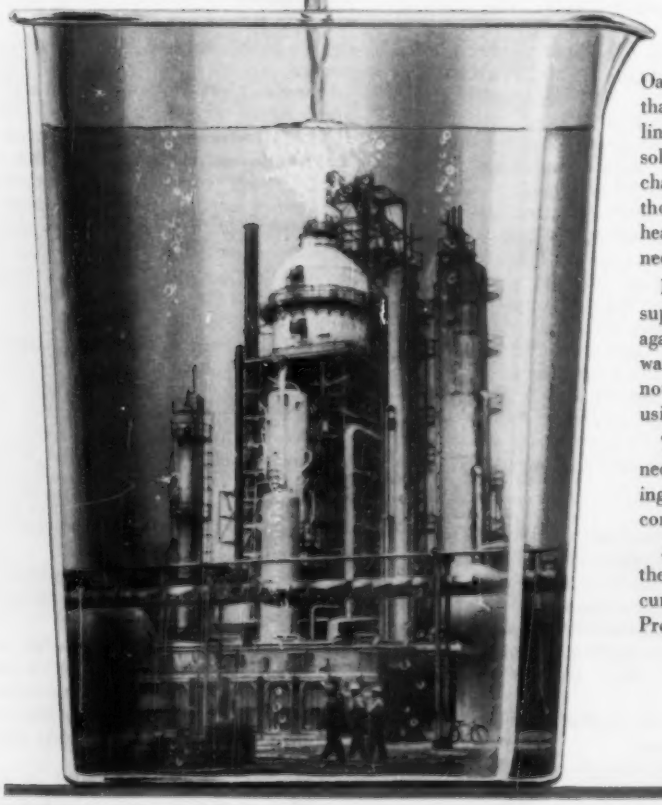

Oakite Acalaid is a newly-developed liquid additive that steps-up the cleaning efficiency of acid or alkaline solutions against problem soils. It contributes solvent action to their detergency. It has a supercharging effect that gives extra power to pry loose those tenacious carbon and scale deposits found in heat exchangers and processing columns. Now you'll need less time to do a more thorough cleaning job.

In just a few months of field testing, Acalaid's supercharging ability has been proved time and time again. To cite one case: At a refinery, the tower that was traditionally toughest of all to clean was pronounced "slick as a hound's tooth" after a turnaround using Oakite 85 and Acalaid.

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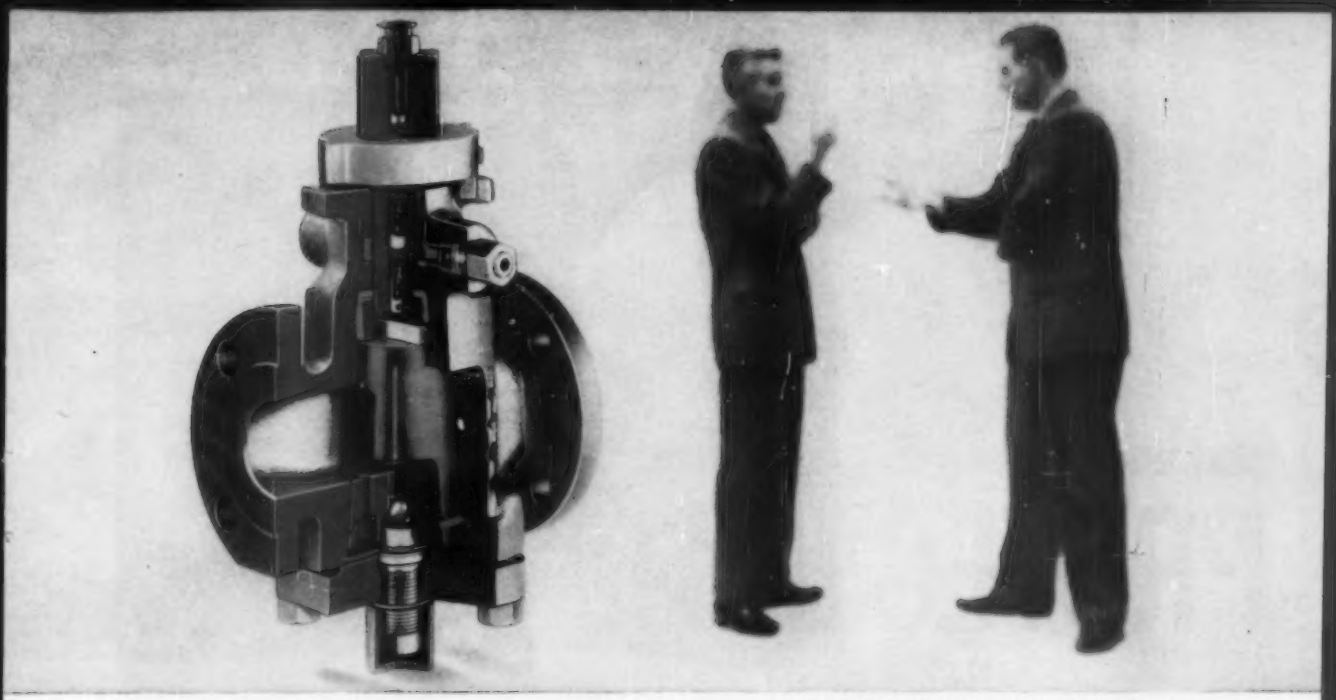
SCIENCE



Rockwell-Nordstrom Hypreseal lubricated plug valve for higher pressure services. Shuts off positively, operates easily, can be repacked in service.

LEADERSHIP INVITES IMITATION

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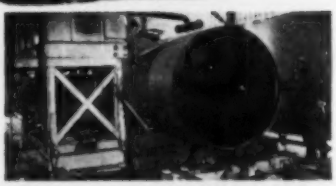

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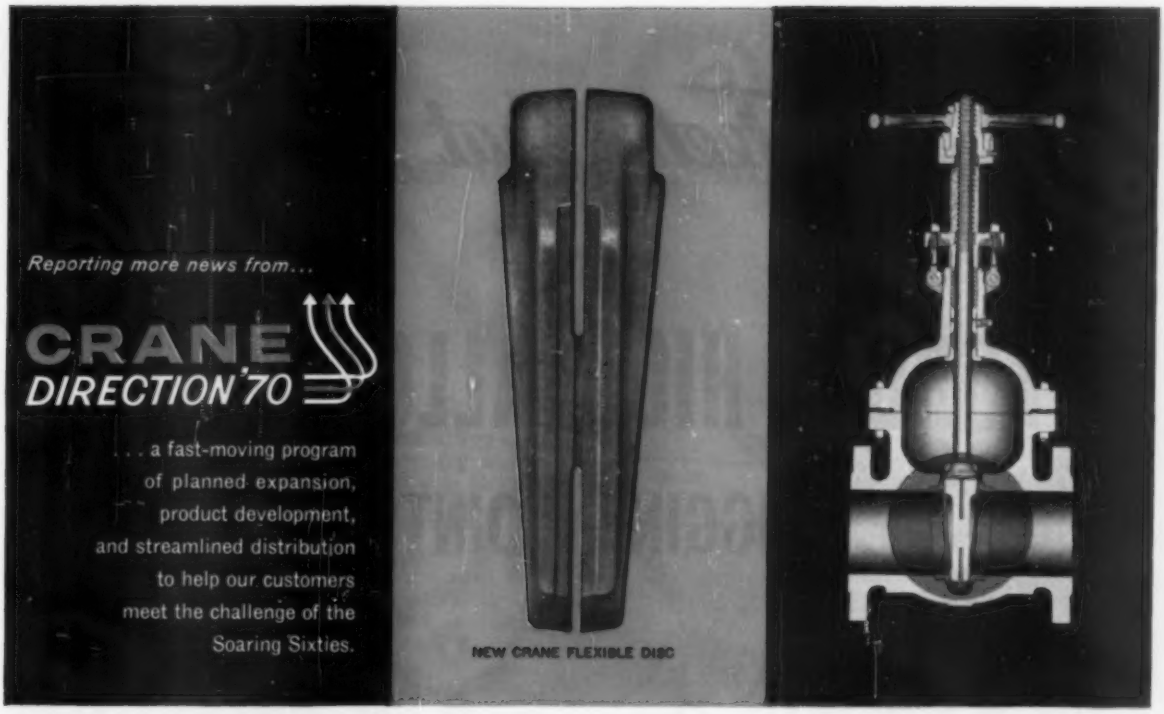

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BECAUSE THEY'RE FLEXIBLE, new Crane Flex Gates seat with less torque.

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Basic Guides to Influencing Others

Robert M. Wald

"It takes two to speak the truth—one to speak, and another to hear."—Henry David Thoreau (1849)

YOU HAVE AN IDEA. You're excited about it. You know it will be more efficient — will save money. But it's not going to get anywhere unless you sell it. It's your idea and you have to be the salesman. Just like any other product, it's worthless sitting on the shelf.

You have to sell it to superiors, to subordinates, to associates, perhaps even to business contacts outside your company.

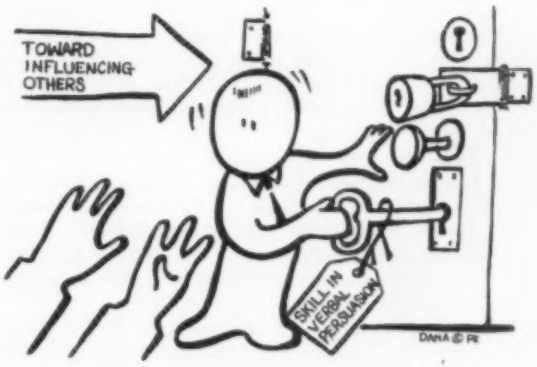
Only to the extent that you are able to communicate and "sell" your point of view, can your ideas be implemented. Only then will you have an opportunity to achieve a position of influence in your organization and in your industry. If you are unable to influence others effectively, your activity will more than likely be looked upon as a "sideline" and your personal and business growth will be limited. Your ability to influence others is basic to your management development and competence.

KEYS OF PERSUASION

There is no doubt that a flare for communication — that is, skill in the use of words and overall language capability — is one of the essentials in influencing others. Beyond this capacity, however, deeply influencing the behavior of a particular individual is dependent upon a thorough understanding of his personal make-up and a realistic self-understanding of your own talents and weaknesses. These are the three main keys to successful persuasion:

DR. ROBERT M. WALD *is vice president in charge of the Western Division of George Fry & Associates. Currently headquartered in Los Angeles, he has been associated with the general management consulting firm for some 10 years and during that time has had day-to-day contacts with executives in establishing programs in organization and long-range planning, management development, and wage and salary administration. His initial association with the firm enabled him to devote a year to study of the characteristics and organizational environment of top corporation officers.*

Dr. Wald attended undergraduate school at Johns Hopkins University. He was awarded the MA and PhD degrees by Northwestern University, and has served on the Northwestern faculty. Prior to joining the Northwestern faculty, he spent two years directing the organization and development of an educational guidance and personnel program. He is a frequent speaker before business and professional groups, and a regular contributor to business and professional journals. He is a member of the American Management Association and a number of other societies.



Hold it! It takes three keys to open that door.

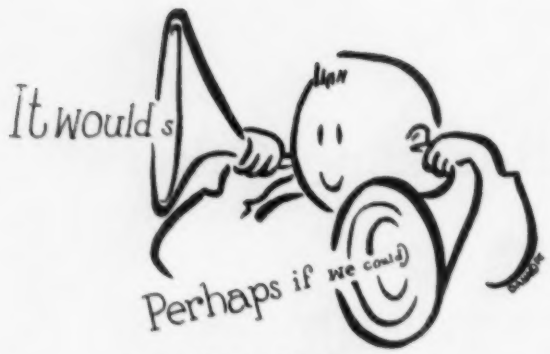
1. **Skill in verbal expression.**
2. **Knowing the person you are attempting to influence through continued attention to "sizing up" his unique psychology.**
3. **Knowing yourself, through a concerted effort to understand your own motivations, prejudices, and overall pattern of behavioral tendencies.**

The last two knowledges underlie your effectiveness as an "influence," despite keen ability with language. Language implies a face-to-face situation. It must be put into context, channeled, and adapted to create a certain idea in a certain person. Without an understanding of the person, it is nondirective, apt to be meaningless, and perhaps apt to convey a completely negative impression. Thus, for example, we have the "huckster" who thinks only of himself and of his personal needs and desires. Likewise, limited understanding of yourself may result in inability to modify your language in accordance with what you have learned of the other person and his personal equipment.

VERBAL EXPRESSION

A great deal has been written on the subject of effective word usage in influencing others, and little purpose would be served to discuss this topic in detail here. However, it should be understood that communicating and influencing are not the same. Communicating, for example, may be merely to pass on factual information. Influencing, on the other hand, implies changing a person's attitudes or motivating him toward a desired decision or action.

Nevertheless, words are the tools of persuasion, and very little real leadership can take place without them. Many people interpret this as meaning that they must "do the talking"; and, unfortunately, are inclined toward spending

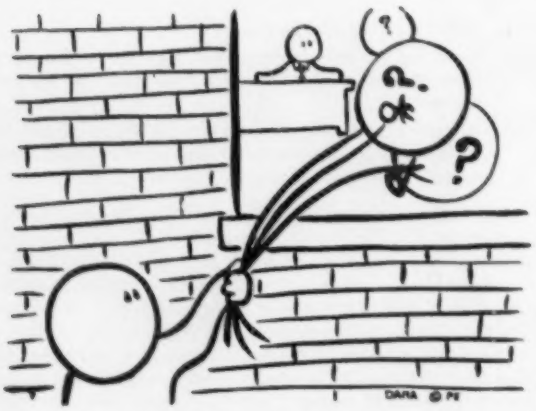


Listen to the other fellow's ideas and use them.

the time of conversation either speaking or thinking only about what they are going to say next. Actually, skill as a listener is a primary requisite of effective communication.

Several tips with regard to influencing others through the use of words are:

1. **Talk less; listen more.**
2. **Use "conversational hooks"** — questions about a person's previous comments or reactions which indicate interest and a desire to explore his thoughts further.
3. **Obtain the person's opinion** on the issue at hand, and convey the impression that his ideas are worthwhile and helpful.
4. **Be "shockproof"** — never apologize or act embarrassed about any turn your discussion may take. Yet, maintain an objective, unbiased manner.



Throw out some trial balloons.

5. **Throw out "trial balloons"** to obtain understanding of the person's point of view.
6. **Practice allowing the other person to "sell" himself on your idea.**

The remarks of one company president concerning a man's management potential are indicative of the thoughts of key executives —

"You can't tell Jim anything. He's always itching to tell you and shuts out your point of view. There's no doubt that he's glib and a good talker — in fact, I like to hear Jim talk — but every time I'm with him I have the feeling he's not really interested in my opinion. On this basis, I seriously question his supervisory and persuasive skills."

KNOWING PERSON TO BE INFLUENCED

As a frame of reference for understanding and influencing others, here is a listing of several of the general background and psychological factors which all people bring to jobs. A relatively long-term association with a person will enable you to evaluate all of them in some detail, whereas a brief acquaintance will provide you an opportunity to analyze only a few. In any case, the more of these characteristics

Examine the person to be influenced.

you are able to pin down, the better the possibility of relating to the individual and, thus, of influencing him.

1. **Background of education and experience**

What opportunities has he had to learn about the matter under discussion? Does he have a high degree of technical knowledge on the subject? How much detail about the problem must be described? What reactions on issues similar to the one at hand has he expressed in the past?

2. **Analytical ability and objectivity**

How skillful is he in dealing with facts, in weighing them, and in arriving at meaningful solutions to problems? Does he examine matters in a penetrating fashion? Is he more apt to be influenced by logical or emotional appeals?

3. **Pattern of interests**

Is he keenly concerned with the problem or must you develop his interest?

4. **Conservativism versus aggressiveness**

Does he typically take a cautious or a forceful approach to problems? Is he inclined to seek out new ideas and methods of implementing them? How much of an overall program will he "buy" at one time?

5. **Open-mindedness**

How receptive is he to the thoughts of others? Does he respond best to a positive, confident, and forceful presentation or to an approach in which his help and guidance are sought? What prejudices and biases does he have that relate to the issue?

6. **Temperament**

Is he basically more irritable or tranquil? To what degree must he be handled with "kid-gloves"?

7. **Approach to people**

Does he enjoy dealing with and conversing with others? How long is he typically willing to listen and to discuss a subject? Is he inclined to be a more outgoing or introverted person?

8. **Self-confidence**

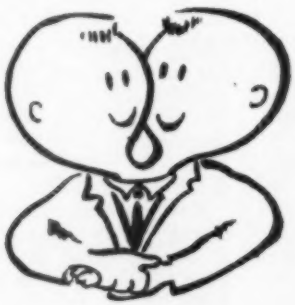
Does he view new ideas as a threat or as an opportunity? Is he defensive or argumentative? To what extent does he worry about making firm judgments and taking decisive actions?

This list of factors is not exhaustive, but merely suggests guidelines that will help you to "know your man." You will be able to think of other characteristics that should be taken into account in your attempt to influence any specific individual. Along this line, you might keep this rhyme in mind:

"To sway John Doe
You would be wise
To see John Doe
Through John Doe's eyes." *(Anon.)*

SELF UNDERSTANDING

The several characteristics mentioned above also provide a focus for self-analysis and self-criticism. The specific questions posed are ones that you can profitably ask about yourself (and probably just did); and the answers, if realistic, should be of substantial assistance in upgrading your ability to relate to the other person. And, of course, only



Know thyself.

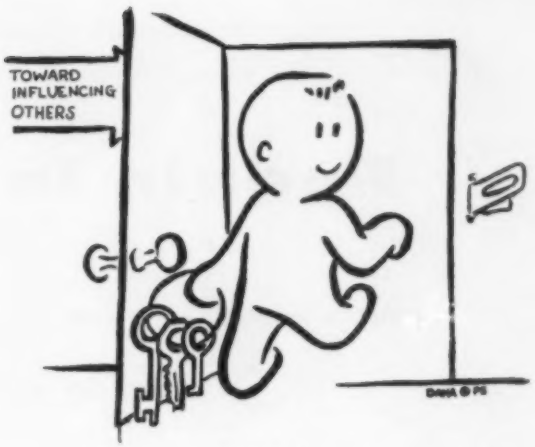
through establishing a favorable relationship can your objective of influencing that person be realized.

As an illustration of the adverse effect of poor self-understanding on influencing a superior, consider for example this remark by the vice president of a major oil company:

> *"Sure, Bill is a superb engineer, but that's just the trouble. He's always so all-fired sure of his ideas that he's irritated when someone wants to discuss them before accepting them. The fact that he's usually right only makes him more resented by the other men. I have considered Bill for chief engineer of this division, but I don't think he can do the job until he recognizes the need for selling himself as well as his ideas."*

Historically, during the Great Depression, controllers led the field in being promoted to positions as chief executive officers. World War II saw many production executives rise to the top. However, recent surveys indicate that marketing and sales executives, who have had excellent opportunities to learn to influence others, are now being appointed to the roles of president and board chairman in their companies. Perhaps this suggests that in normal times, and particularly in this time of keen competition and high spending, those who have acquired skill in influencing others are being given the major consideration for advancement.

It is interesting, also, to note that one of the principal characteristics of top-level corporate executives is constant attention to understanding their personal assets and shortcomings. All of us would do well to develop such a "soul searching" attitude toward enhancing our management skills.



With these three keys in hand you are on your way to influencing others.

SUMMED UP

The major tasks of management are the coordination of group effort toward established objectives and bringing about improvement that will result in increased company growth and development. To the maximum extent, therefore, it is important that a manager develop competence in influencing subordinates, superiors, and business contacts in general. To do so he must give careful attention to upgrading his language skills, to understanding the fundamentals of human behavior, and to developing in himself increased insight into his own motivations and management responsibilities.

Questions for Thought:

1. In what ways do "communicating" and "influencing" differ?
2. What are your major strengths and weaknesses related to ability to influence others?
3. How well do you succeed in your attempts to understand your superiors, subordinates, associates, and general business contacts?
4. What is your level of self-understanding?
5. What are the ingredients of your personal development program, particularly in improving your ability as an "influencer"?

References for Further Reading

[1] *Calhoun and Kirkpatrick, "Influencing Employees Behavior," New York: McGraw-Hill, 1956.*

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[3] *Given, Wm. B. Jr., "Bottom-Up Management," (People Working Together) New York: Harper, 1949.*

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[6] *Rogers, C. R. and Roethlisberger, F. J., "Barriers and Gateways to Communication," Harvard Business Review, July-August, 1952, p. 46.*

[7] *Wald, R. M. and Doty, R. A., "The Top Executive-A Firsthand Profile," Harvard Business Review, July-August, 1954, p. 45.*

★ ★ ★

People in Petroleum

Employees number 2.9% less

Total pay and benefits up 2.7% — per employee up 5.8%

Shareholders increase 7%

"Respect for the dignity and worthiness of every individual is the basis for all employee relations."

This statement in Cosden Petroleum Corporation's annual report echoes the tone of employee relations statements made by petroleum companies in their annual reports. Clark Oil and Refining pointed out that although its annual accounting of company's affairs must deal primarily with dollars and barrels of oil but the year's accomplishments and, more importantly, the future progress of the company depended basicly upon the skills and the quality of relationships between employer and employee.

As you can see by the table, the drop in number employed in 1959 was only 2.9%. With all the reorganization going on in large companies and the tightening up going on in all firms, big and small, this is a remarkably small change. It amounts to only 17,915 compared to the 611,172 still employed by those who gave the number of employees in our annual report survey. This is not much different from the overall production trends in the United States.

Not all companies had fewer employees. Signal Oil and Gas added 1485 new employees in 1959; Phillips, Conoco, American Petrofina all had more people.

At the same time, wages and benefits have taken another step higher. Overall, they are 2.7% above last year. Allowing for the decrease in number of employees, this represents an approximate 5.8% rise in wages given throughout most of the industry last year.

Total capital employed for each employee has gone steadily upward in the petroleum industry. While total number of hours worked has declined, labor cost per production worker has substantially increased and this increase in turn leads to heavy investment in labor-saving machinery.

With our list (see table) the average capital employed for each worker is $45,570. Compare this to capital investment in manufacturing as a whole last year which averaged $15,300 per worker and with the farm average of $20,700 per worker. This also compares very well with the companies who gave their individual cost of investment per employee.

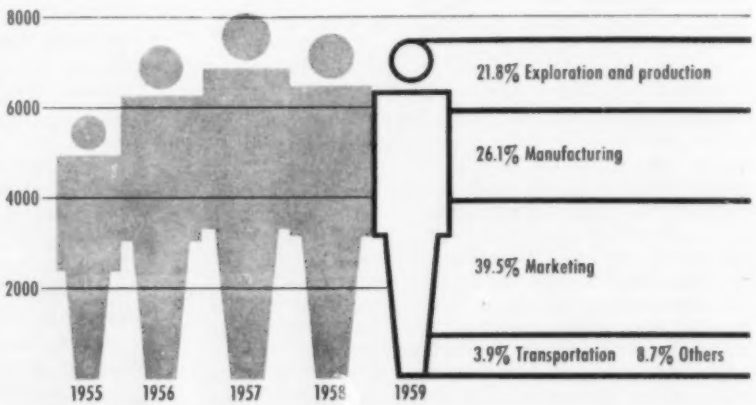
Shareholders Increase

Offhand you would think that numbers of shareholders of common stock would go down because of decline of stock prices on the stock market. It seems unusual then that during a period of sagging prices number of shareholders increased 7%. Jersey Standard had the largest total, which was 79,000 stockholders added to make its present 582,000. In fact, more shareholders were added to the list of Jersey owners during 1959 than in any other year in the company's history.

Husky Oil Company also had a record. Number of new shareholders of common stock almost doubled in fiscal 1959 to a total of approximately 4500.

Strikers Had to Fight

For the first time in many years there was real opposition to striking employees at oil refineries. Standard Oil Company (Indiana) had strikes at five of its refineries in 1959. One at Sugar Creek, Missouri, began on July 8, 1959, and continued past the end of the year. In its annual report the company explains that they found themselves with



Number and distribution of employees

British-American gives number of employees by division in this chart. B-A employees in 1959 averaged 7450 down from 7660 in 1958 and 8000 in 1957.

a forced choice . . . "either we had to penalize current operations by accepting strikes or achieve an accord that involved surrendering at the bargaining table a vital element in our future efficiency.

"We chose to invest in and protect the future. Wages were not an issue. Although many demands were introduced, essentially only one issue was at stake — and still is at Sugar Creek: Is management to retain its responsibility to manage by determining the number of employees and how they are to be reasonably assigned to a given task or must it abrogate that responsibility by granting veto power to the union?"

At Shell's Wood River refinery the "Oil Workers' Council," composed of 11 craft unions, struck on January 30 "in support of a demand that the company commit itself to make all work assignments in strict conformity with jurisdictional lines established by the respective unions. The strike was settled about two weeks later when the unions accepted a prior offer by the company to confirm in writing its willingness to endeavor generally to follow craft lines in making work assignments to the extent that this could be done without causing delays, inefficiencies or increased costs."

Management Development

More space in 1959 annual reports was given to development of executives than ever before. Reported Texaco:

"Continued emphasis was placed on the company's several programs to insure a reservoir of competent managerial talent. The college recruiting program was expanded. Training courses within the company for personnel at the managerial level of all departments are proving to be most effective in developing the type and quality of manpower required in the conduct of the company's expanding operations."

Conoco's comments were in the same

Average Salary and Benefits per Employee

1950	$4,759
1951	5,104
1952	5,312
1953	5,514
1954	5,749
1955	5,990
1956	6,302
1957	6,684
1958	6,980
1959	7,344

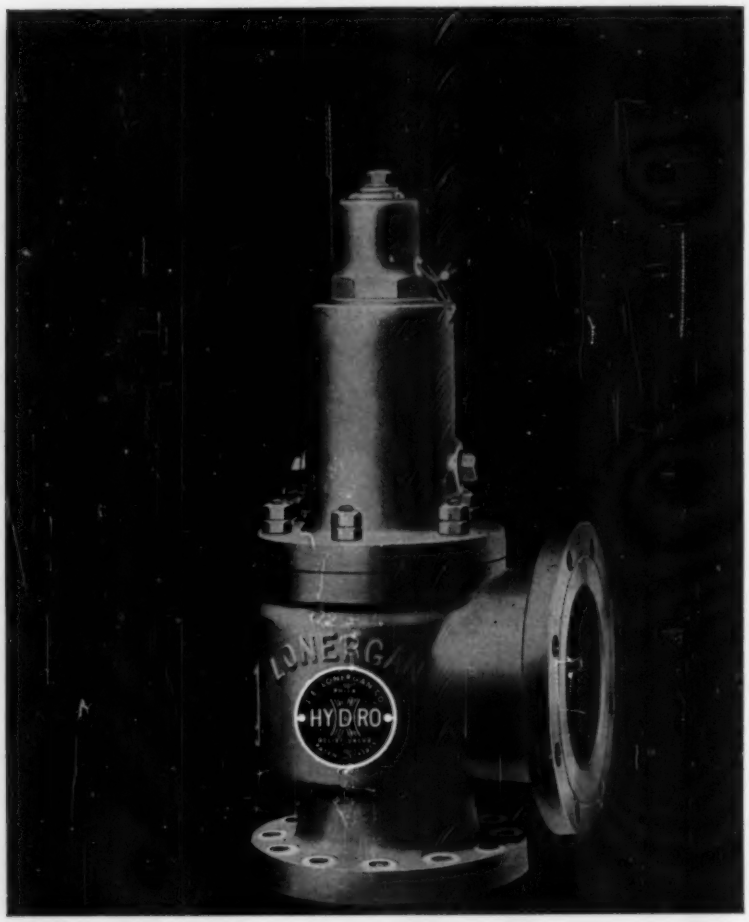
Richfield Oil sets out average salary and benefits per employee for the last 10 years. The figures are slightly higher than the average — $7067 estimated for 1959 and $6635 for 1958.

TABLE 4. PEOPLE IN PETROLEUM

Company	Holders of common stock		Employees, average		Payrolls & benefits ($1000)	
	1958	1959	1958	1959	1958	1959
American-Petrofina	—	—	1,150	1,175	—	—
Ambassador Oil	485	3,163	148	168	111	112
Anderson-Prichard	7,000	7,735	917	910[1]	6,534	6,596
Argo Oil Corp.	5,192	5,453	182	185	—	—
Ashland O. & Ref.	38,766	41,944	4,600	4,600	3,778	3,970
Atlantic Ref. Co.	51,923	53,149	16,247	15,394	112,747[2]	112,680[2]
Aztec O. & G.	7,989	9,214	36	47	—	—
Blackwell O. & G.	673	743	55	60	—	—
British American	34,975	34,967	7,660	7,450	46,000	47,400
Champlin O. & Ref.	18,290	19,608	1,503	1,536	1,714	1,779
Cities Service Co.	173,000	172,000	18,700	18,000	—	—
Clark O. & Ref.	—	—	2,500	2,880	—	—
Coastal States	2,600	3,400	141	201	447	682
Colorado Oil O & G.	7,097	7,103	1,330	1,400	353	431
Continental Oil	31,017	37,550	11,117	11,333	75,478	80,399
Cosden Petroleum	8,000	11,000	950	1,070	6,138	6,496
Delhi Taylor	12,000	15,000	659	681	380	460
Drilling & Exploration	2,300	2,400	363	337	2,856	2,800
Eason Oil Co.	516	502	131	125	566	587
Frontier Ref. Co.	1,798	1,851	616	505	—	—
General American	4,591	4,553	532	503	3,032	3,000
General Crude	1,143	1,156	212	209	1,566	1,589
Getty Oil Co.	13,485	14,348	532	588	—	—
Gulf Oil Corp.	93,580	100,805	56,000	50,700	312,752	302,447
Helmerich & Payne	3,500	3,700	625	514	2,953	3,202
Honolulu Oil Corp.	4,711	5,505	667	730	1,019	1,300
Hugoton Prod.	5,100	4,850	75	75	—	—
Husky Oil Co.	2,923	4,500	788	725	4,038	4,284
Intex Oil Co.	1,071	980	85	78	708	697
Kendall Ref.	2,709	2,772	685	658	3,774	3,840
Kerr-McGee	5,736	5,890	2,981	3,411	17,753	18,399
Leonard Ref.	4,497	4,500	676	656	347	416
Louisiana Ld. & Exp.	9,751	9,678	115	115	1,010	1,053
Macmillan Petroleum	1,832	1,468	295	248	—	—
Midwest Oil	7,353	7,128	127	135	—	—
Monterey Oil	4,609	4,600	382	403	3,159	3,232
Murphy Corp.	1,350	1,370	632	808	3,671	4,423
Ocean Drilling & Exp.	943	950	278	270	1,565	1,378
Ohio Oil Co.	43,514	43,769	6,453	7,534	44,707	55,970
Phillips Petroleum	127,749	135,523	24,459	24,575	182,789	190,558
Plymouth Oil Co.	8,676	9,058	938	927	7,596	7,356
Producing Properties	2,027	4,625	114	176	751	1,316
The Pure Oil	46,078	47,711	10,981	10,740	73,064	74,939
Quaker State	6,502	6,392	1,398[1]	1,448[1]	7,397	7,954
Republic Natural	5,100	5,000	314	307	267	258
Richfield Oil	11,783	12,204	6,260	6,374	43,694	46,808
Shamrock O & G.	6,735	6,941	962	990	6,400	6,700
Shell Oil	19,307	19,730	38,572	38,217	325,352	341,567
Signal O & G	10,760	13,381	1,691	3,176	12,211	16,149
Sinclair Oil Corp.	116,165	119,802	23,828	23,557	165,002	168,332
Skelly Oil	5,857	6,167	4,817	4,787	31,173	32,262
Socony Mobil	207,000	224,000	43,700[3]	40,900[3]	357,100[3]	354,200[3]
South Penn	10,459	11,047	2,323	2,341	12,456	13,317
Standard Oil Calif.	152,754	159,707	38,395	38,390	280,624	299,543
Standard Oil Indiana	151,937	158,553	46,033	43,569	352,469	348,411
Standard Oil N. J.	503,000	582,000	154,000	146,000	953,000	969,000
Standard Oil (Ohio)	37,535	37,915	11,138	10,690	77,917	80,254
Sun Oil Co.	25,954	27,375	17,521[4]	17,292[4]	121,721	128,149
Sunray Mid-Continent	105,575	110,590	5,599	5,894	36,653	41,688
Texaco Inc.	138,380	143,344	54,999	53,956	328,386	341,514
Texas Pacific	5,402	5,765	474[1]	449[1]	3,367	3,496
Three States	12,000	12,500	103	98	671	668
Tidewater	20,911	23,589	9,459	9,361	62,297	64,098
TXL Oil Corp.	8,100	8,900	68	79	—	—
Union Oil of Calif.	51,700	50,400	7,873	7,846	60,925	64,933
Union O & G of La.	1,352	2,163	418	425	—	—
Universal Consol.	2,900	3,400	83	76	791	725
Wilcox Oil & Gas	2,022	2,000	122	115	798	764
TOTAL	2,433,439	2,599,086	647,787	629,172	4,164,103	4,274,655

[1]At year end.
[2]Payroll only.
[3]U. S. only.
[4]Oil Division.

QUIET!



New Lonergan liquid relief valve doesn't chatter; eliminates product waste; reduces maintenance

Ever hear a relief valve chatter? They all do! They shout their faults to the world, while beating themselves to death. When you can hear one, you know product is being wasted; maintenance costs are increasing; employees are growing annoyed; and perhaps dangerous, flammable liquids are running loose.

Now you can install a Lonergan Hydro-Valve guaranteed not to chatter, hammer, or drum, *yet still deliver full rated capacity !* Gone is the need to install an oversized valve or a high-priced, heavyweight regulator valve to eliminate chatter on by-pass and emergency relief applications.

The Lonergan Hydro-Valve does not contain any capacity-reducing gimmicks or gadgets to eliminate chatter. Instead, it is designed to be completely quiet under all operating conditions. It proves itself so on hundreds of applications every day.

Bellows models of the Lonergan Hydro-Valve are also available for corrosive applications. The elimination of chatter and its associated bellows flexing action, greatly extends bellows life and virtually ends the need for expensive bellows replacement. *Full details are in a Hydro-Valve bulletin. Write for a copy today !*

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vein: "In 1959 Continental's program of personnel and management development focused particular attention on qualifying people in the organization to fill managerial openings created by the company's expansion. Key executives were enrolled in advanced educational programs to enhance their management skills. Seminars were held to improve the communications techniques and abilities of supervisory personnel. Each department made a forecast of its personnel requirements and identified employees having potential for advancement."

Stated Tidewater: "Important moves were made in 1959 to insure that the company's future is in the hands of strong and capable managers. The first step was establishment of a plan of organization designed to decentralize operations to the maximum extent practicable and to centralize policy-making, planning and control to the degree necessary to insure attainment of the company's objectives."

Sun Oil Company reported: "To help employees improve skills necessary to keep pace with the company's growth, several training and development programs were expanded. During 1959, a new group of promising candidates for greater responsibility completed a comprehensive employee development program in the general offices. Included in the series were talks by company executives and group discussions of latest management techniques."

Quaker State Oil Refining described its policy this way: "Over the years the company has concentrated on improving the quality and depth of its employees. This policy was implemented in 1959 by added communications to employees by management with scheduled monthly meetings, wherein officers and staff members presented company policy and other matters to the foremen and supervisory group. These meetings will continue in 1960."

Educational Aid

Many companies support individual programs of education and development. Standard Ohio is one that gives scholarships to company people:

"Realizing that support of education is a privilege and an obligation of good corporate citizenship, the company has for many years awarded scholarships on a competitive basis to children of Sohio employees, dealers, distributors, and jobbers, under the Sohio Scholarship Plan."

Richfield has begun a new plan to promote training, according to its report: "A program was initiated during the year to provide financial assistance to employees who voluntarily undertake college or trade school courses of

SPECIAL REPORT TO CATERPILLAR OWNERS:

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... cost less per hour

Converting to Lifetime Lubricated Track Rollers costs less than you think

Lifetime Lubricated Roller Groups, including seals, shafts and end collars, *cost only a little more* than ordinary Bellows Seal Rollers without end collars. But this small expense of *initial* installation rapidly disappears through noticeably lower owning and operating costs.

Based on savings from seal replacement alone, Lifetime Lubricated Rollers soon make up the difference. The metal rings of the Floating Ring Seal can be used over and over again. Take a 14-roller D8. At every roller rebuild, you probably have to buy 28 bellows seals @ $3.97* each or a total of $111.16. Compare this with the rubber "O" rings costing a total of only $45.08*. You save $66.08 in seal replacement costs every time you rebuild or replace. Similar savings are available on all models. And, replacement Lifetime Lubricated Roller and shaft assemblies without end collars are priced below those of Cat Bellows Seal Rollers.

But your savings don't end here! Here are other benefits you get from Lifetime Lubricated Track Rollers:

1. Longer Lived Roller Shells and Component Parts. The Lifetime Lubricated Roller is much stronger and has more metal in the wear zones, specially hardened for extra resistance to wear. And bushings, bearings and shafts are larger and stronger and will last longer. These components are *always* bathed in *clean,* heat-dissipating oil (not grease). Dirt just can't get in to accelerate wear—oil can't get out, thanks to the patented Floating Ring Seal. This means you won't be buying as many replacement bushings and shafts at rebuild or roller replacement time.

2. Maintenance Is Eliminated. Lifetime Lubricated Rollers need no servicing until they're finally rebuilt. You don't have to spend any time nor money for lubrication during the rollers' lives.

3. Easier Installation. Snap-on rings hold seals and end collars in place *before* mounting. End collar bolt holes line up easily with track roller frame holes at installation. Your tractors will be on the go much sooner.

See your Caterpillar Dealer. He'll give you the complete facts on the economy of investing in Lifetime Lubricated Rollers . . . for *all* Caterpillar track-type equipment.

Caterpillar Tractor Co., General Offices, Peoria, Illinois, U. S. A.

* Suggested consumer prices for these Caterpillar parts

SERVICE TIP: Lifetime Lubricated Rollers need no servicing. But when rebuild time finally comes, keep metal rings matched in original pairs.

CATERPILLAR

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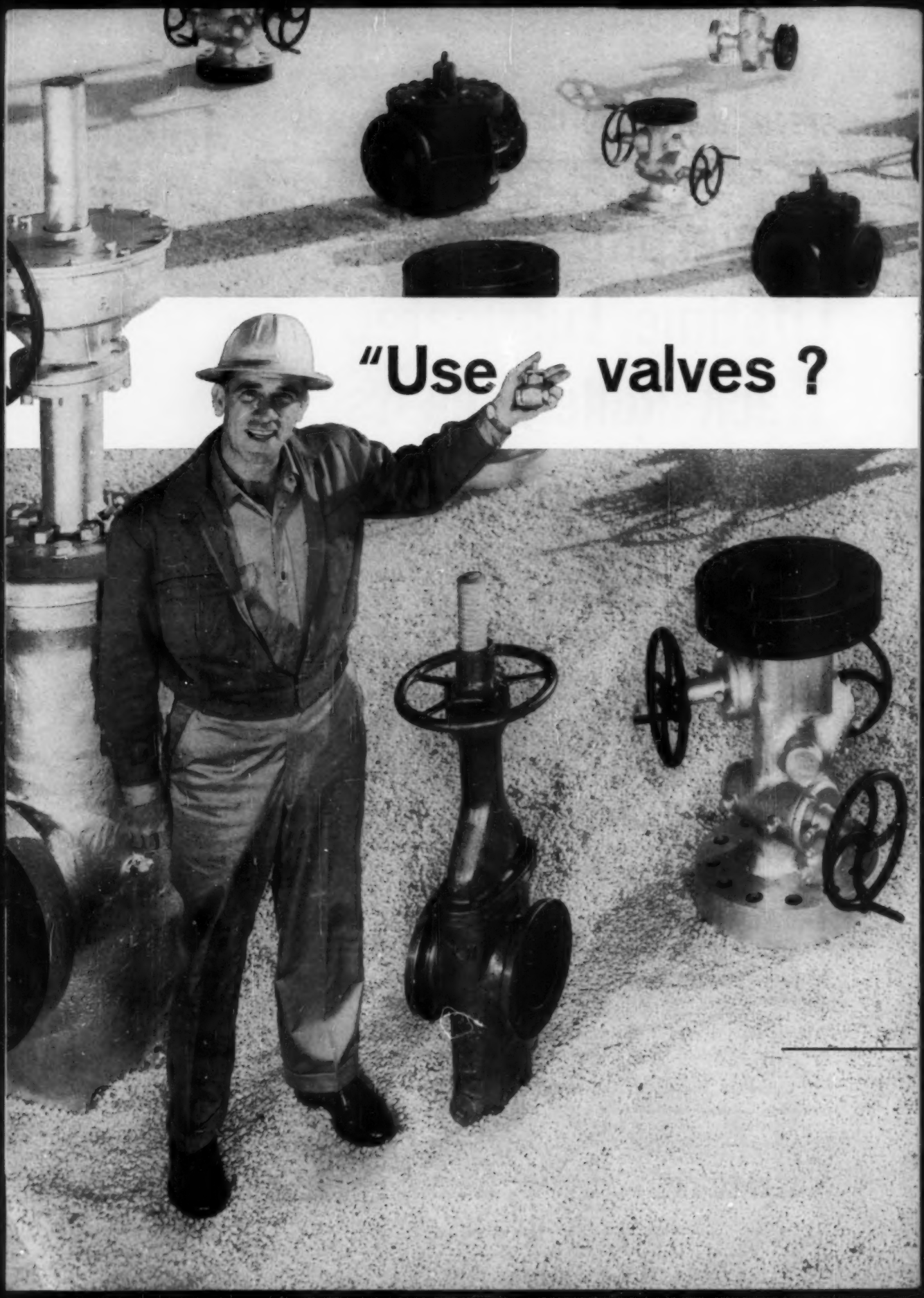
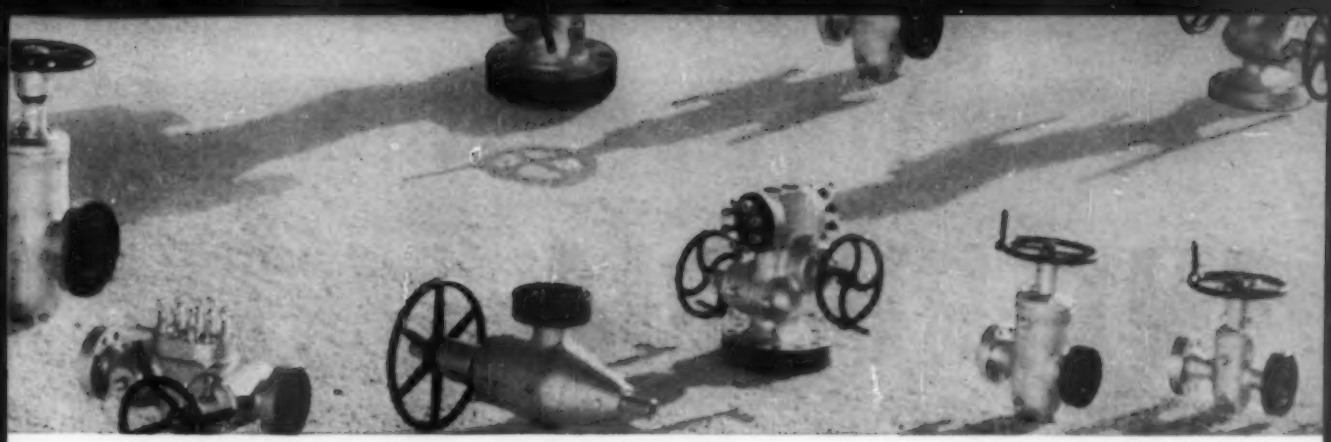

"Use valves ?



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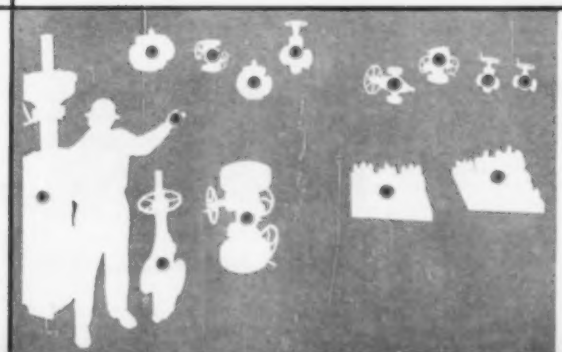


For complete information on valves by W-K-M, write for the following catalogs:

CATALOG 200: ① Standard API Gate Valves ② Balanced Stem Gate Valves ③ Multiple Completion Gate Valves ④ Cross Type Gate Valves ⑤ Regular Port Gate Valves. **CATALOG 300:** ⑥ Standard ASA Gate Valves. **CATALOG 400:** ⑦ ACF Lubricated Plug Valves. **CATALOG 1000:** ⑧ ACF Non-lubricated Ball Valves. **CATALOG 1200:** ⑨ Pressure Sealing Gate Valves.

5923

INTERURBIA

Growth Market for the Gas Age

Concentrated in the New York-Newark Interurban complex are more natural gas consumers than in any single *state* of the union. Not satisfied to remain America's Number One Market for consumer goods and services, Interurbia expects to grow another 10% this year.

Such a unique combination of growth and stability means unequaled security for gas producers supplying this modern City State of the Gas Age. Via Transco, producers in Texas and Louisiana can tap the market where the most people are.

TRANSCONTINENTAL Gas Pipe Line Corporation

study of an educational or vocational nature which are related to a field of work within Richfield's operations. The objective is to aid employees who, on their own initiative, strive for personal development in order to achieve more effective long-range job performance."

Contributions such as fellowships, grants to universities and colleges, and aid to teachers are a common practice for the larger petroleum corporations.

Public Affairs

Company relations with the public became a subject of deep interest and, as all important company matters, was discussed thoroughly in annual reports.

Sunray Mid-Continent states its objective in this phase is "to win understanding and good will for the company and its subsidiaries" and declared: "One important function of the public relations staff is to counsel management and all departments on decisions which directly or indirectly affect the company's relationships with the public."

In its report, Phillips Petroleum describes its "Corporate Citizenship" this way: "Over the years, we have shared common interests with local citizens and gained much experience in establishing good community relations. This background, coupled with the company's longtime policy of encouraging Phillips people to take active parts in community life, has caused good corporate citizenship to become a hallmark of the company."

Public affairs as they are related to the government got some comments from several concerns. Gulf Oil Corporation reported: "The Governmental Relations Department in Washington, D. C., Mr. Kermit Roosevelt, vice president, was enlarged with responsibility for maintaining major contacts on the national and international level, and for the development of information pertaining to legislation and related activities. Staff members are responsible for tax and other legislative liaison between the company and governmental agencies and for public relations functions."

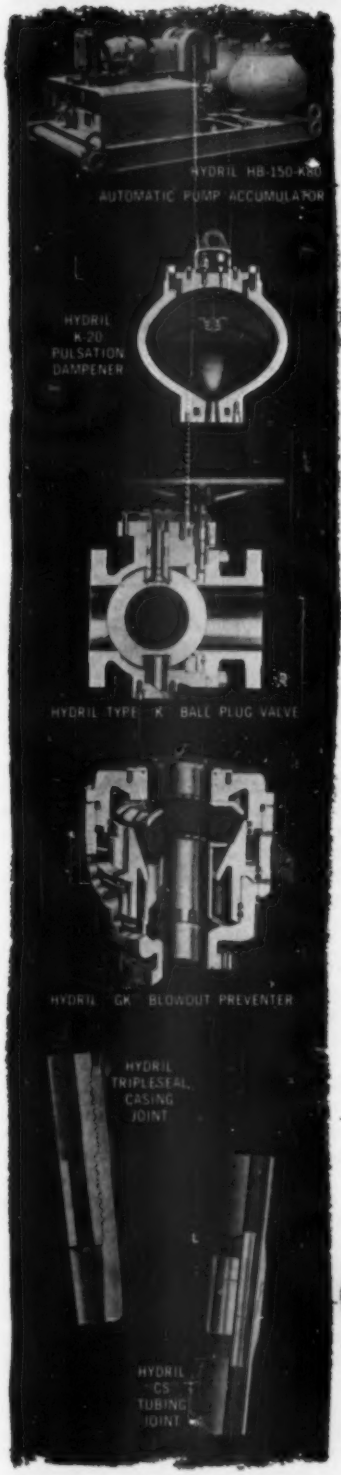
Under the title "Future of private enterprise depends on public understanding" Ohio Oil says: "During 1959 we continued to study the impact of increased governmental regulation and taxation, and the effect of new legislative proposals. Informing employees and the public about these issues is a responsibility which we have attempted to meet more adequately.

"We have encouraged, on a nonpartisan basis, more active participation in government by employees through distribution of voter registration and get-out-the-vote materials." ★ ★ ★

Ernestine Adams

HYDRIL has the SAFE answers

TO DRILLERS' PRESSURE-CONTROL PROBLEMS!



above-ground

No blowout prevention control program is better than the power available to operate it, and HYDRIL AUTOMATIC PUMP ACCUMULATORS made to match Hydril Blowout Preventers, assure safety in *any* control system by providing a constant, instantly available source of hydraulic power to actuate hydraulically operated blowout prevention equipment. Choice of engine or motor driven units, in a wide range of hydraulic storage capacities.

To take dangerous vibration out of rotary hose, HYDRIL PULSATION DAMPENER absorbs surge at the reciprocating mud pump . . . saves possible injuries to drilling crew . . . saves damage to costly equipment.

All drilling fluids—abrasive or not—are handled with equal ease by HYDRIL TYPE "K" NON-LUBRICATED BALL PLUG VALVES. New patented compressible port seal is the secret of seep-proof shutoff, continued easy operation. Hydril Ball Plug Valves always work on the first try . . . can't stick or freeze . . . require minimum maintenance to stay in perfect working order.

in-the-cellar

HYDRIL BLOWOUT PREVENTERS successfully contain dangerous downhole pressures while permitting various sized members of the drill string to pass in and out of the hole . . . will actually pack off the open hole in complete safety!

Type "GK" for high-pressure wells, "MSP-2000" for low and medium pressures, "GK-6-10000" for highest pressures.

downhole

You're steps ahead with Hydril's two-step thread. HYDRIL CASING JOINTS make up and break out faster because you make up two threads at once. They save running time . . . hold greater pressures because they seal at *three* places.

The same holds true for HYDRIL TUBING JOINTS. Pressure-tight when made up, you can depend on them to stay that way. There's a wide range of Hydril Joints for faster, safer drilling and completion operations.

HYDRIL INSIDE BLOWOUT PREVENTERS . . . Well Guard; Drill Pipe, Tubing and Casing Plugs; Drill Pipe Float Valves and Back-Pressure Valves . . . effectively block downhole pressures inside the pipe while the Hydril Blowout Preventer is effectively sealing off the annulus.

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Management Personals

Edwin S. Wright was appointed assistant secretary of Esso Standard Division of Humble Oil & Refining Company. He has been manager of the wage and salary division of Esso's employee relations department. He succeeds **Alan R. Martin Jr.,** who moved from Esso headquarters in New York City to Houston, Texas, when he was recently named assistant secretary of the Humble company.

Thomas M. Welch will head a newly created plans division for benefit-plan development in the new Humble Oil & Refining Company.

He was manager of the plan development and social security division of Esso Standard Oil Company, which merged into the Humble company. Welch transfers from New York to Texas as part of Humble's headquarters staff in Houston.

Garry Owen, a vice president, was elected a director of Arabian American Oil Company. He has been with Aramco since 1941. Prior to joining Aramco he practiced law for 12 years in San Francisco and joined Standard of California in 1939. Now stationed in Washington, D. C., Owen is in charge of government relations affairs for Aramco in the U. S.

Mohamed Selman, head of the Permanent Petroleum Office of the Arab League in Cairo, will organize the Second Arab Oil Congress being held in October this year in Beirut. A skilled oil diplomat, he is at present traveling the Arab countries to cover preliminary arrangements for the Congress. He has also been invited to Caracas at the invitation of the Venezuela Government which, as last year, will send an official delegation to the meetings. He estimates that the 550-600 attendance at the First Congress in Cairo will be dwarfed by an expected 900-1000 delegates and oil industry representatives.

Chester S. Crawford was elected a director of American Meter Company. He is president and a director of the Whitehall Cement Manufacturing Company, a director of Interstate Railroad, a director of the Portland Cement Association and trustee of Lankenau Hospital.

Harold S. Skinner, assistant to the president and director of public affairs of Continental Oil Company, was promoted to manager of public affairs and public relations. In his new position, he will also become a member of the company's management executive committee. **Emerson G. Smith,** who is currently director of public information, continues in that position. **John Post,** manager of industrial relations, was named to the newly created position of director of industrial and personnel relations. In his new position, he will serve as special advisor to the president on industrial and personnel relations.

The name of the industrial relations department changed to the personnel relations department. **Vance A. Knight,** who is currently assistant manager of industrial relations, was promoted manager of personnel relations.

Reese H. Tucker of Bartlesville, Oklahoma, was elected a vice president of Cities Service Company. In his new post Tucker will serve as coordinator of exploration and production for the Cities Service system, and transfers from Bartlesville to the New York headquarters of the parent company.

R. H. Tucker

D. J. Jones

David J. Jones was appointed manager of a newly formed investment analysis department which will provide continuing analytical study of capital expenditure and investment programs of Standard Oil Company (New Jersey) and its affiliates. He has served as assistant treasurer since 1957.

L. D. Stinebower was elected treasurer of Jersey Standard succeeding **E. G. Collado** who was elected a director. Stinebower has served as executive assistant to the chairman of the board. **D. E. Stines** was named executive assistant to **Leo D. Welch,** recently elected chairman of the Jersey board.

Lawrence A. Kimpton has joined the Standard Oil Company (Indiana) where his assignment will be to travel in the United States and abroad to study the company's widespread facilities and operations. He will report to **John E. Swearingen,** president.

The move will be effective when Kimpton's successor as chancellor of the University of Chicago is elected. He has been a member of Standard of Indiana's board for 2 years.

Frank V. Martinek, for 35 years active in investigation and security for Standard (Indiana), has retired as assistant vice president.

E. R. Krouse, supervisor of Ohio Oil Company's tax department, was appointed financial assistant to the vice president of domestic production, and **D. E. Cacy,** assistant controller of the Tulsa (Okla.) production division, named controller of the Casper (Wyo.) production division. **R. N. Bishop,** Ohio Oil auditor headquartered at Findlay, will succeed Cacy at Tulsa.

L. J. Qualkenbush, controller of the Oasis Oil Company of Libya, a subsidiary of Ohio Oil, will become assistant supervisor of the production accounting department at the general office. **V. L. Burns,** Ohio Oil auditor, is assigned to the Marathon Pipe Line Company, an Ohio Oil subsidiary, and appointed assistant supervisor of the pipeline accounting department.

John Ricca, formerly general purchasing agent for Arabian American Oil Company and Aramco Overseas Company, was appointed manager of purchasing and traffic for the Oasis Oil of Libya. Oasis Oil recently was incorporated to conduct exploration, development and transportation operations in Libya for the Ohio Oil Company, Amerada Petroleum Company and Continental Oil Company. The three companies, jointly associated in Libya since 1956, have made a number of promising oil and gas discoveries on their Libyan concessions.

A. R. Tuttle, a staff assistant in Ohio Oil's law organization, was appointed assistant to the treasurer.

Dr. W. J. Yost is research director of a new analytical department formed to furnish analytical assistance to technical departments at the research center as well as operating organizations of Ohio Oil. Appointed supervisor is **Dr. W. P. McKinnell Jr.,** former advanced research scientist at the center.

Marvin H. Grove was named chief executive officer and chairman of the executive committee of The Walworth Company.

Abbas Ghaffari was named manager of the new National Iranian Oil Company branch office in New York City. The offices were established to bring closer commercial relations with U S.

John A. McGuire, president of Three States Natural Gas Company since 1952, was named to the newly-created post of chairman of the board. He will be succeeded as president by **William H. Hudson.** Hudson has been associated with Three States as a director for more than 5 years, during which he also served for a time as a vice president before resigning to assume direct supervision of his personal properties. **Lee Van Atta,** vice president, was elected to the board of directors.

▸ **F. G. Fabian Jr.,** was elected executive vice president of Dresser Industries, Inc. He has been president and general manager of Dresser Manufacturing Division at Bradford, Pennsylvania since 1955. **Charles Kuhn,** who has been vice president and sales manager of Dresser Manufacturing Division, was promoted to president.

John V. James was promoted to controller of Dresser and transfers from Olean, New York, to Dallas, Texas. James has been vice president-finance of Clark Brothers Company at Olean.

J. D. Mayson, formerly secretary, was promoted vice president and secretary of Dresser. In his new position he directs the legal, tax and insurance activities.

▸ **P. S. Magruder** was named assistant to the president of Mobil Oil. Executive vice president of General Petroleum Corporation until the merger of that company with Mobil, Magruder will serve as the personal representative of Mobil's president, **Herbert Willetts.** He will reside in Los Angeles and will be principally concerned with the Pacific Coast area.

Magruder will be proposed by Mobil to fill the vacancy on the board of Western Oil and Gas Association created by the retirement of **Robert L. Minckler,** senior vice president.

▸ **D. C. Wimberly** has transferred from Standard Oil Company of California, Western Operations, Inc. to California Research Corporation, San Francisco, and appointed technical assistant to the vice president—petroleum products research department.

▸ **E. H. Hermsen,** Los Angeles, was elected corporate secretary of Tidewater Oil Company, succeeding **W. J. Burker,** of New York, who has retired. Hermsen has been assistant corporate secretary in the Los Angeles home office since 1955, and previously served as an attorney in the firm's legal department.

Russell D. Richardson, vice president-finance, also has retired.

▸ **E. L. (Woody) Hiatt,** vice president of Union Oil Company, has assumed full responsibility for all the company's operations in its Glacier division. With headquarters in Great Falls, Montana, he will be responsible for exploration and production, refining, transportation and supply, marketing and all related services.

▸ **Thornton F. Bradshaw,** business leader, author and management specialist, was elected president of the Chamber of Commerce of Greater Philadelphia. Bradshaw is vice president of the Atlantic Refining Company and general manager of its finance and accounting department.

▸ **R. W. McDowell,** formerly vice chairman of the board, was elected to succeed **C. H. Wright** as chairman of Sunray Mid-Continent Oil Company. Wright became chairman of the finance committee.

S. D. Breitweiser, formerly executive vice president of DX Sunray Oil, was named president of that company succeeding McDowell to the leadership of Sunray's refining and marketing subsidiary.

All other officers of Sunray Mid-Continent were re-elected including **Paul E. Taliaferro,** president and chief executive officer; **W. C. Whaley,** chairman of the executive committee; **R. E. Foss,** senior vice president directing production; **H. O. Harder,** senior vice president directing exploration; **R. P. Henry,** financial vice president and treasurer; **John H. Douma,** vice president and manager of western division located at Denver, Colo.; **M. Darwin Kirk,** vice president and general counsel; **J. M. Linehan,** vice president and manager of supply and transportation; **Lewis Lacy,** secretary and assistant treasurer; **J. C. Bumgarner,** controller, and **W. Terrell Johnson,** general auditor and manager of tax department.

▸ **Dr. Ernest O. Kirkendall,** secretary of the American Institute of Mining, Metallurgical, and Petroleum Engineers, has received an Alumni Award from his alma mater, Wayne State University, Detroit, Michigan, for his distinguished achievement in the science of metallurgy.

▸ **W. R. Stott** and **Herbert Willetts,** New York oil company executives, were elected to the board of directors of the American Petroleum Institute. The board also elected **Morgan J. Davis,** president of Humble Oil & Refining, to its executive committee. Davis has been a board member since 1957.

Stott, a vice president of Jersey Standard replaces **Eugene Holman,** who recently retired as chairman of the same company, a committee member since 1945. Willetts, president of Mobil Oil and executive vice president of Socony Mobil, replaces **R. L. Minckler,** senior vice president of Mobil Oil, Los Angeles, on the board since 1949.

▸ **Charles E. Webber** was appointed director of natural gas administration, heading a newly-organized group responsible for supervision of natural gas sales and the accompanying FPC certificate applications, gas rate filings, rate investigations and related matters. He formerly was technical adviser to the vice president in charge of production. Also announced were the appointments of **H. Douglas Coe,** formerly of Sun's Dallas and Washington, D. C., offices, as assistant director of natural gas administration, and **John A. Ward III,** who moves from Dallas to Philadelphia as attorney for the new group.

J. Harold Perrine named assistant director of industrial relations for Sun Oil. Perrine, formerly administrative manager of research and engineering department, is succeeded by **Bruce L. Ritz.**

For

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Meetings . . .

July 28-30 — **API Division of Production**, eastern district meeting, Greenbrier Hotel, White Sulphur Springs, W. Va.

Aug. 15-17 — **American Society of Mechanical Engineers — American Institute of Chemical Engineers**, heat transfer conference and exhibit, Statler Hilton Hotel, Buffalo, N. Y.

Aug. 29-31 — **20th Annual Appalachian Gas Measurement Short Course**, West Virginia University, Morgantown, West Virginia.

Sept. 8-9 — **Mid-Continent Oil & Gas Assn.**, annual membership meeting, Louisiana-Arkansas Division, Roosevelt Hotel, New Orleans, La.

Sept. 11-13 — **New Mexico Petroleum Industries Committee**, annual convention, Western Skies Hotel, Albuquerque, N. M.

Sept. 11-16 — **American Chemical Society**, national meeting, New York City.

Sept. 12-14 — **The Asphalt Institute**, Division 1, management committee meeting, Point Clear, Ala.

Sept. 14-15 — **Western Petroleum Refiners Assn.**, Rocky Mountain regional technical-industrial relations meeting, Henning Hotel, Casper, Wyo.

Sept. 14-16 — **National Petroleum Assn.**, annual meeting, Traymore Hotel, Atlantic City, N. J.

Sept. 15 — **Natural Gasoline Assn. of America**, Rocky Mountain regional meeting, Palliser Hotel, Calgary, Alberta, Canada.

Sept. 18-21 — **American Society of Mechanical Engineers**, petroleum mechanical engineering conference, Jung Hotel, New Orleans, La.

Sept. 19-21 — **Texas Mid-Continent Oil & Gas Assn.** annual meeting, San Antonio, Tex.

Sept. 20-21 — **Illinois Oil Industry** convention, St. Nicholas Hotel, Springfield, Ill.

Sept. 20-21 — **Water Lift Institute**, Court House, Liberal, Kans. Sponsored jointly by the Southwest Kansas Petroleum Industry and the State Board for Vocational Education.

Sept. 20-21 — **American Gas Assn.**, organization meetings, Hotel Cleveland, Cleveland, Ohio.

Sept. 23-24 — **Assn. of Desk & Derrick Clubs**, annual convention, Sheraton-Cadillac Hotel, Detroit, Mich.

Sept. 25-27 — **American Assn. of Oilwell Drilling Contractors**, annual meeting, Roosevelt Hotel, New Orleans, La.

Sept. 25-28 — **American Institute of Electrical Engineers**, petroleum industry committee, Hotel Skirvin, Oklahoma City, Okla.

Sept. 29-30 — **Mid-Continent Oil & Gas Assn.**, Mississippi-Alabama division meeting, Grand Hotel, Point Clear, Ala.

Oct. 2-5 — **Society of Petroleum Engineers of AIME**, annual fall meeting, Denver, Colo.

Oct. 4-5 — **Gas Measurement Institute**, National Guard Armory, Liberal, Kans. Sponsored jointly by the Southwest Kansas Petroleum Industry and the State Board for Vocational Education.

Oct. 6-7 — **National Assn. of Corrosion Engineers**, annual Western region conference, Sheraton-Place Hotel, San Francisco, Calif.

Oct. 6-8 — **National Assn. of Corrosion Engineers**, Southeast region conference, Dinkler-Plaza Hotel, Atlanta, Ga.

Oct. 10-12 — **American Gas Assn.**, annual convention, Atlantic City, N. J.

Oct. 11-14 — **National Assn. of Corrosion Engineers**, Northeast region conference, Prichard Hotel, Huntington, W. Va.

Oct. 12-14 — **Southwest Federation of Geological Societies**, annual meeting, Abilene, Tex.

Oct. 13-14 — **California Natural Gasoline Assn.**, annual fall meeting, Hotel Miramar, Santa Monica, Calif.

Oct. 19-20 — **National Assn. of Corrosion Engineers**, North Central region conference, Schroeder Hotel, Milwaukee, Wis.

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Fond Mother: "Willie, you've been a naughty boy. Go to the vibrator and give yourself a good shaking."

Getting up before the sun rises is just a matter of mind over mattress, according to one member of the morning tour.

The aged mourner slowly limped to the bier and for a long time stood there staring at the face of his departed friend. The funeral director approached him. "How old are you, sir?" he said.

"I'm 98," came the whispered reply.

Holding him by the arm the funeral director asked: "Hardly worth going home, is it?"

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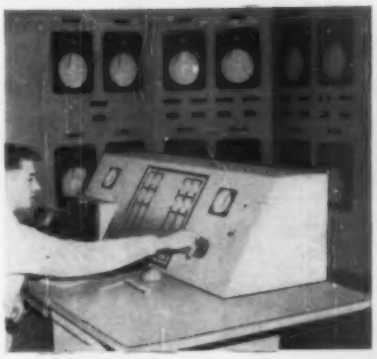

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American® telemetering and telecounting equipment helps one man do the work of many ...in gathering fields, transmission and distribution systems.

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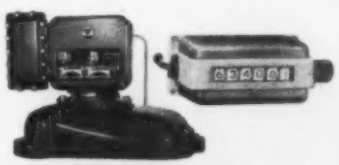

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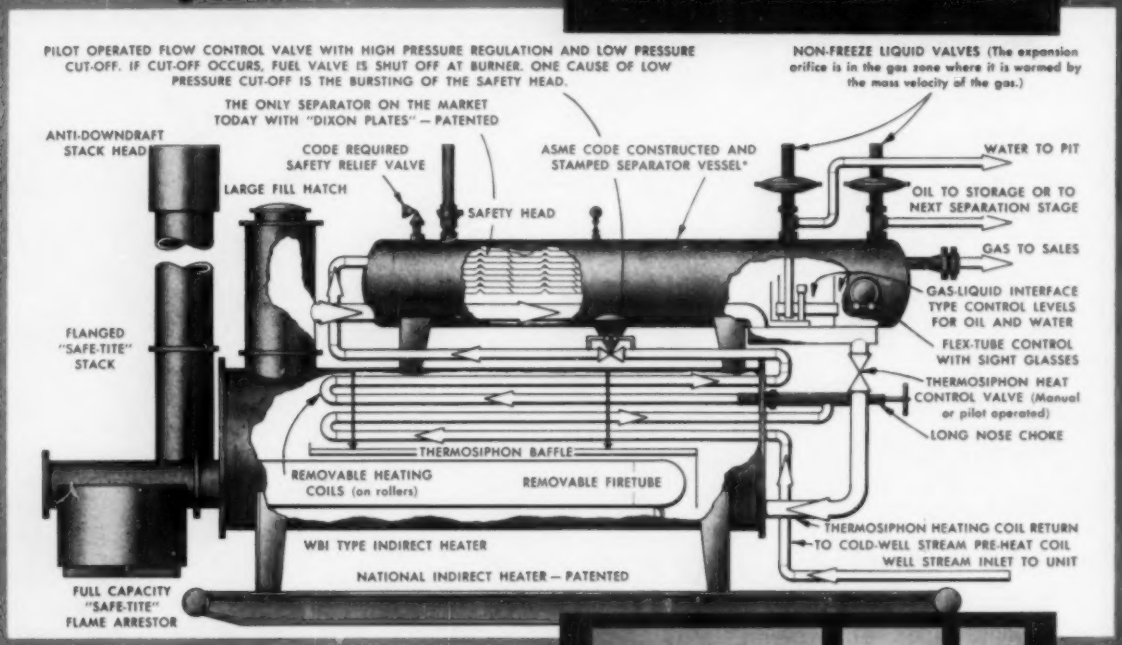
PILOT OPERATED FLOW CONTROL VALVE WITH HIGH PRESSURE REGULATION AND LOW PRESSURE CUT-OFF. IF CUT-OFF OCCURS, FUEL VALVE IS SHUT OFF AT BURNER. ONE CAUSE OF LOW PRESSURE CUT-OFF IS THE BURSTING OF THE SAFETY HEAD.
NON-FREEZE LIQUID VALVES (The expansion orifice is in the gas zone where it is warmed by the mass velocity of the gas.)
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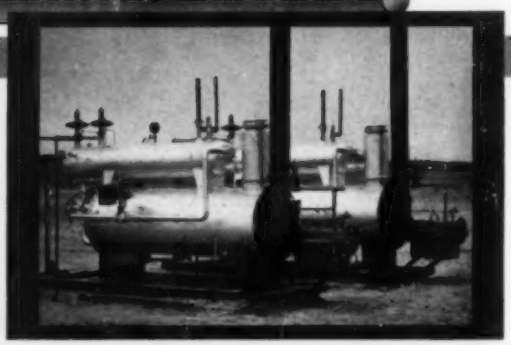

National Thermosiphon Stak-Paks are composed of standard separator and indirect heater units. They are available in combinations of two or three-phase horizontal separators together with any size indirect heater. Completely skid mounted and pre-piped, the ASME code stamped separator is not immersed in the water bath of the heater but is placed above. Glycol protected water bath will not freeze. No housing or insulation needed in moderate climates such as Oklahoma, Kansas and Texas.

The Stak-Pak is available with all controls and valves manufactured by National . . . one supplier — one source . . . non-freeze type liquid valves, FLEX TUBE® liquid level controls, interface level controls, long nose chokes and many others PLUS National's 'Safe-Tite' Flame Arrestors and safety-drilled return bends in heating coils.

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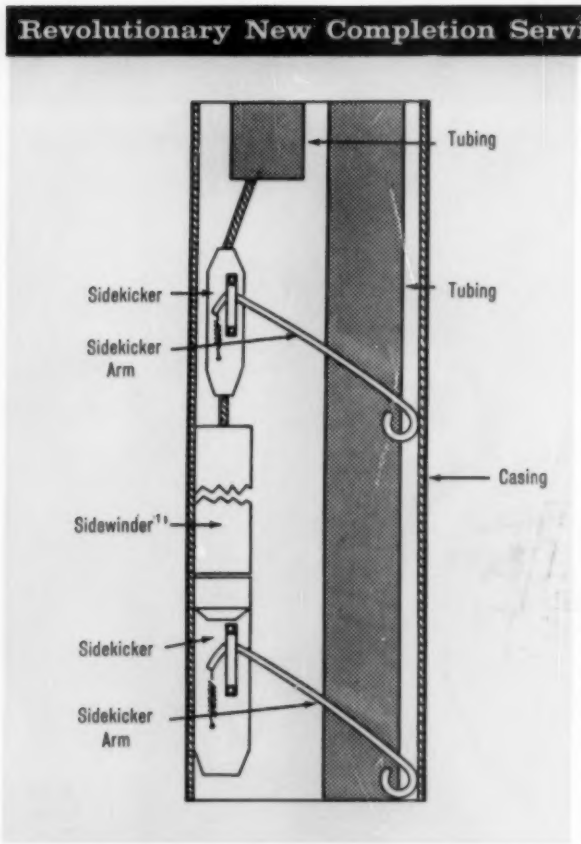

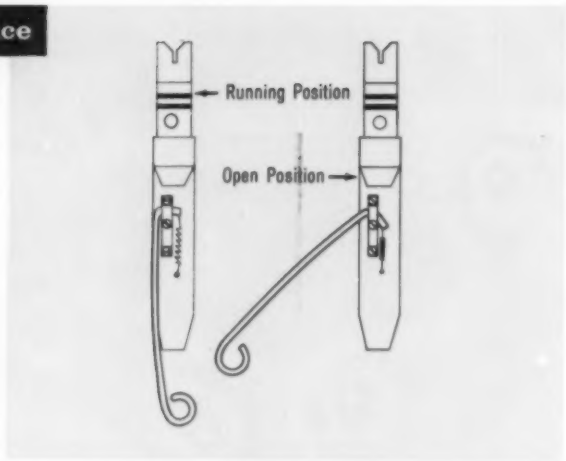

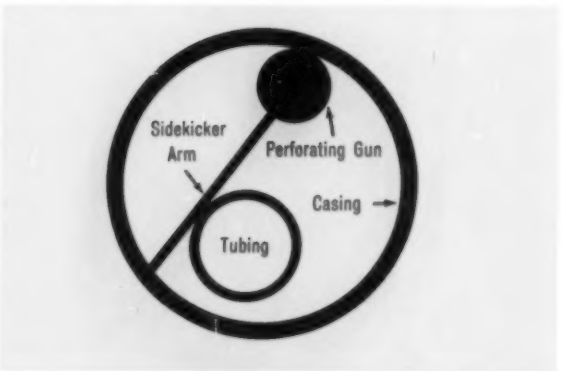

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*** Permanent Well Completions**

Welex engineers have answered the problem of perforating an upper zone with no risk to the adjacent tubing string in dual permanent well completions. The new development — another first by Welex — offers these advantages:

- Service can be performed through 2″ tubing and standard seating nipples.
- The Sidekicker, a mechanical orienting decentralizer developed by Welex, forces the Sidewinder[1] perforating gun against the side of the casing, assuring maximum penetration.
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- Absolutely no debris is left in the hole. All debris is retained in the carrier and returned to the surface.

Welex, the company that originated jet perforating proudly adds this new service to the other "firsts" that it has introduced to the oil industry.

In Permanent Well Completions, as well as in other types of completions, Welex has a complete set of tools for every job. Next time and every time let Welex's completion services work for you.

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[1]*Trademark of Jet Research Center, Inc.*

Of Things To Come . . . In Oil

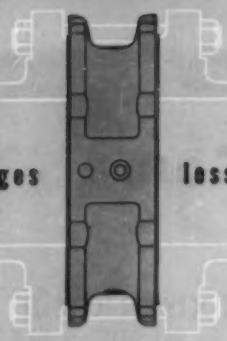
"FUTURE RECOVERY FROM EXISTING OIL FIELDS in the United States may be as much as 90 billion bbl," says Paul D. Torrey, University of Texas, in a report presented to the Interstate Oil Compact Commission. Application of known improved recovery methods will add more than 44 billion bbl to proved reserves of more than 30 billion bbl. Additional oil will come by more experience in those states where these improved methods have not been utilized.

CALIFORNIA PRODUCTION WILL START UPWARD TREND this year, reversing a decline started in 1953. H. G. Vesper, president, Standard Oil Company of California, Western Operations, Inc., forecasts that the level of production of California crude and natural gasoline liquids will reach 1 million bbl per day by 1966. Vesper told the recent Pacific Coast District API meeting that the increase will come from development of offshore production and progress in secondary recovery techniques.

GEOLOGICAL EVALUATIONS BY MACHINE will handle more geological data in one year than geologists have succeeded in processing over the past 150 years. Gulf Oil Corporation scientists have developed a new geological language which will permit electronic evaluation of tons of data in a fraction of the time normally required. Maps "drawn" by the machine are as accurate as man-made maps and are compiled in a much shorter time.

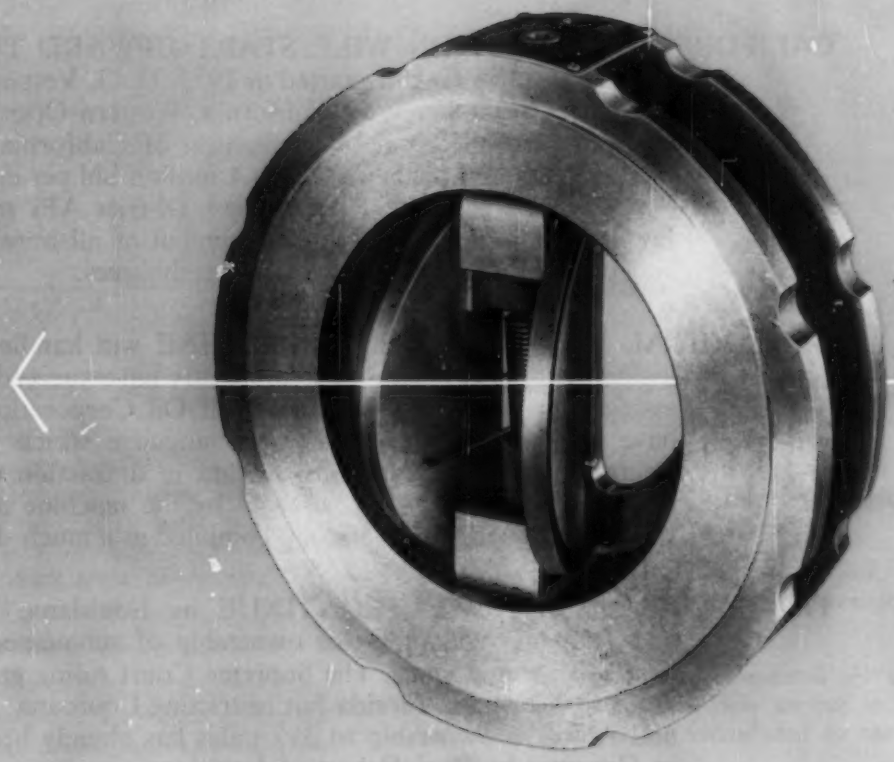
TIDELANDS BATTLE WILL CONTINUE as Louisiana, Mississippi, and Alabama will press for ownership of submerged lands out to the 10½-mile mark. The Supreme Court ruling granting such lands to Texas and Florida but restricting Louisiana, Mississippi, and Alabama ownership to 3½ miles has already been attacked in Congress by Rep. Hebert of Louisiana.

TEXAS "OIL SANDS" WILL BE MINED, according to plans of Ted Pursley, San Antonio. Pursley plans to sink a 7-ft shaft to the top of the Green and Navarro sands, found between 195 and 276 ft in Bexar County. About 300 drain holes will then be drilled into the oil-bearing sands. Core analysis of the sands show 37 ft of effective pay with permeability too low for waterflood recovery. Pursley expects to produce 200 to 400 bbl per day.



fits between the flanges

less space—weighs only 10% as much



Mission Duo-Chek valves

Mission Duo-Chek Valves weigh approximately 10 per cent as much as conventional check valves. Smaller, lighter Duo-Chek Valves mean that you save on space, weight, installation, and price. But, you are getting a check valve with a bubble-tight seal, anti-slam closure, long life built in. No load is carried on the plate hinges. No external parts. No lubrication required.

The sine wave seal prevents seepage, yet holds without leaking or distortion at maximum test pressure. The sealing material is molded and bonded into a metal groove, making an "O"-ring type seal. Pressure deforms the packing. Metal-to-metal contact completely encloses the sealing material, preventing pinching off under pressure. Available in steel, 316 stainless, aluminum, and bronze to fit ASA raised face or ring joint flanges.

MISSION VALVE AND PUMP CO. A SUBSIDIARY OF MISSION MANUFACTURING CO.
P. O. BOX 4200, HOUSTON, TEXAS CABLE ADDRESS "MISSCO" • EXPORT OFFICE: 30 ROCKEFELLER PLAZA, NEW YORK
In the United Kingdom: MISSION MANUFACTURING CO., LTD., 1 Hanover Square, London W. 1 England • cable address "MISSOMAN"
Sold by Mission Manufacturing Company outside of Canada and the U.S.A.

MISSION VALVE AND PUMP CO.

How much CF&I Casing and Tubing *should go into this new well?*

Someone once asked Abraham Lincoln, "how long should a man's legs be"? The president replied, "long enough to reach the ground". The same is true of CF&I Seamless Casing and Tubing. You need enough to protect your investment and bring oil to the surface.

Why should you insist on CF&I Casing and Tubing? Because it is made from top grade steel . . . subjected to strict quality control throughout every stage of production . . . and meticulously manufactured in one of the most modern mills in the industry.

CF&I's Seamless Casing and Tubing mill is only hours away from the heart of the oil country. This assures rapid delivery — either directly from our Pueblo, Colorado mill or through our network of strategically located distributors.

All CF&I Casing and Tubing exceeds API Specifications. It's available in sizes 2⅜" to 9⅝" O.D. For complete information or technical service, contact a nearby CF&I sales office.

7610

CF&I STEEL **SEAMLESS** *casing and tubing* API

THE COLORADO FUEL AND IRON CORPORATION • DENVER, COLORADO

BEFORE
Your Well Requires
Pumping Equipment

Mat Dodson (left), manager of Production Equipment Division, and field superintendent check equipment requirements on well soon to go on the pump.

The time to prepare for your pumping equipment needs is BEFORE your well pressure drops too low. That's just good field operation.

Get an accurate and engineered estimate of your production equipment needs from the Production Equipment Division of Wilson Supply. Veteran equipment men, like Mat Dodson (pictured above), can be of real help and service to you. They know equipment . . . they know the field conditions in your area. They are experienced hands at working with operators to select equipment best suited for individual pumping unit operations. Contact your Wilson Production Equipment representative for all your pumping equipment needs. He's a good man to know!

contact your
WILSON SUPPLY
Production Equipment Man

MAIN OFFICE and WAREHOUSE • 1301 CONTI STREET • HOUSTON, TEXAS
INTERNATIONAL DIVISION • 45 ROCKEFELLER PLAZA • ROOM 1701, NEW YORK

"WHAT YOU WANT – WHEN YOU WANT IT"

WILSON SUPPLY CO
HOUSTON TEXAS

6024

FASTER, MORE DEPENDABLE DRILLING

with two nickel alloy steels

You are looking at the business end of the drilling string.

Anything at this end is strictly "on its own" once the rig goes into action. Here's where a metal's properties prove themselves . . . one way or the other.

Metallurgists at Reed Roller Bit Company of Houston say: "In Reed 'Y' Bits, research and experience have shown that nickel steels are essential to toughness in critical stress and wear points."

To give their new "Y" bits the properties they need, Reed Roller Bit Company uses two nickel alloy steels . . . for the bit lugs, 0.40-0.70% nickel steel, AISI 8720 . . . for the cutters, 3.25-3.75% nickel steel, AISI 4815.

Rock bits are just one example among thousands of what can be done with nickel alloy steels to give heavy-duty equipment needed properties. So, for dependable service look to the equipment made with nickel steels. If you would like to have information on the ways in which nickel-containing alloys improve oil field equipment, just write us. It's available for the asking.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

You save drilling dollars with a Baroid Mud Program

THE MUD PROBLEM AND ITS SOLUTION

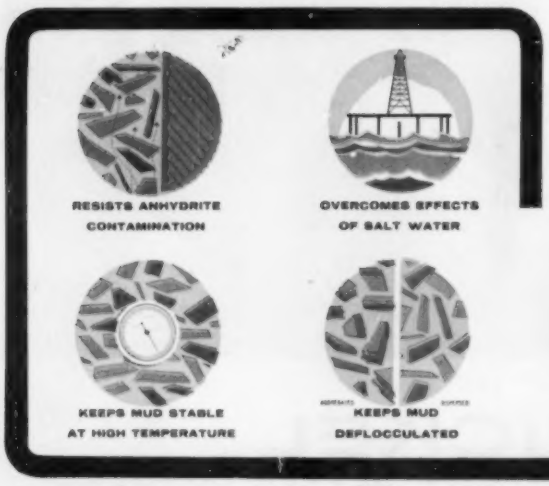
Q-BROXIN*

When your drilling problem is to reduce viscosity and gels in salt, gyp or fresh water muds, Q-BROXIN is your answer.

For example, in a complete Baroid mud program used on a well in Timbalier Bay Field, Lafourche Parish, Louisiana, a Q-BROXIN — bay-water mud was successfully maintained in spite of salt water flows and adverse shale conditions. The total mud cost was only half that of wells to similar depths. Over 14,000 feet of 9⅝" casing was set and cemented without difficulty.

Q-BROXIN mud treatment controls flow properties in the presence of calcium and chloride contamination and such muds are stable at high temperatures. Inhibited muds are easy to control with Q-BROXIN.

A Baroid mud program *is planned* to give *you* drilling success and *save your drilling dollars.*


RESISTS ANHYDRITE CONTAMINATION
OVERCOMES EFFECTS OF SALT WATER
KEEPS MUD STABLE AT HIGH TEMPERATURE
KEEPS MUD DEFLOCCULATED

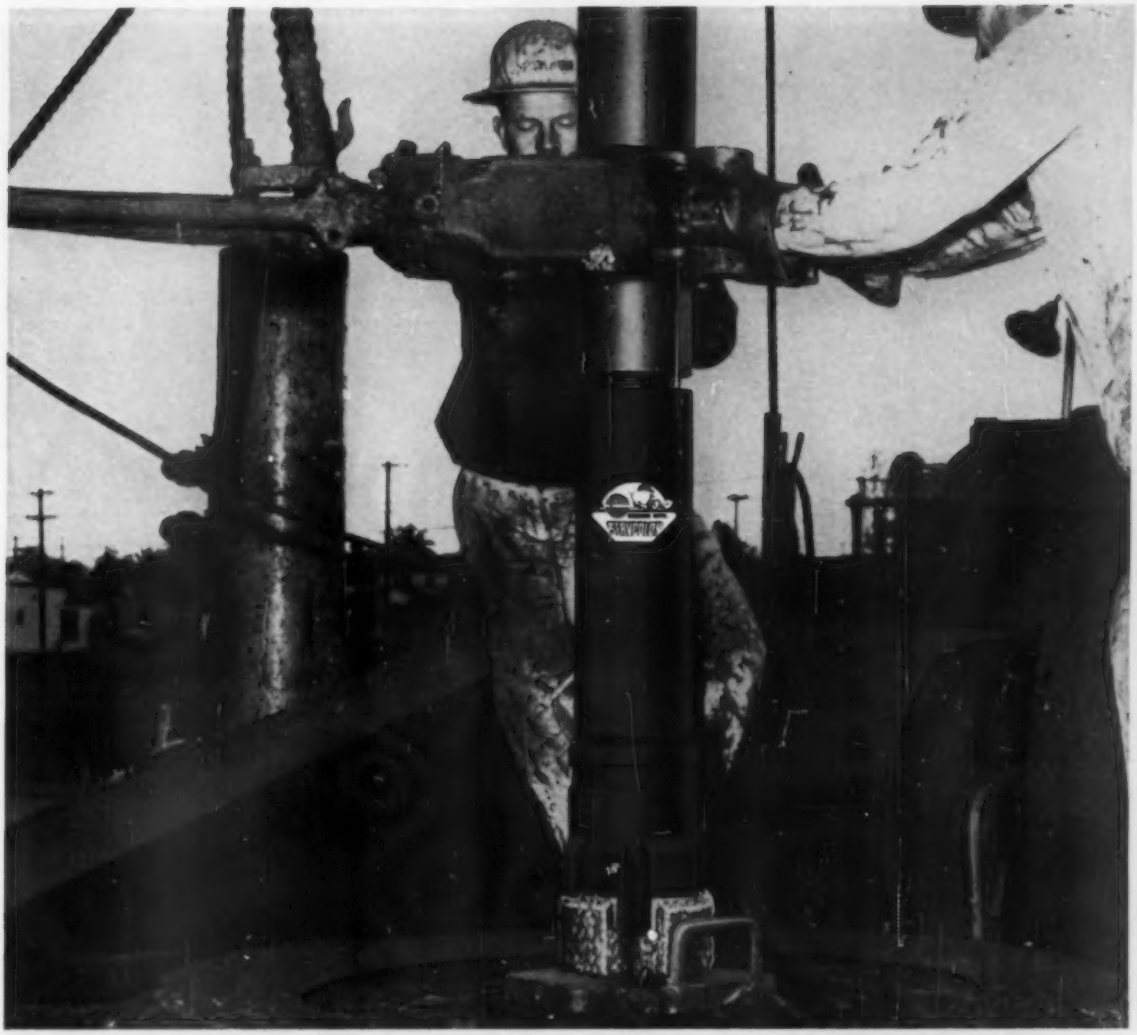
BAROID

BAROID DIVISION NATIONAL LEAD COMPANY

MAIN OFFICE: P. O. BOX 1675, HOUSTON 1, TEXAS

*Registered Trademark, Puget Sound Pulp and Timber Company.

6030



Three 6⅛″ Bit Cones milled up in 2 HOURS!

Servcoloy-dressed Junk Mills chew up bit cones and other junk with amazing speed; makes this method of removing a fish fast, safe, and very economical.

After three cones from a 6⅛" bit were left on bottom, two rock bits, two hydro-bailers, and two junk baskets were run during a three-day period in attempts to either recover or sidetrack the three cones. Results were negative.

A six-inch Servco CJ Junk Mill dressed with Servcoloy, was then run in the hole. A total of two feet of hole was drilled in a period of two hours of milling. The operator ran back with a bit and proceeded to drill ahead. Fine steel cuttings were caught on the shaker during the milling and appeared on the mud screen during the succeeding day, showing that the *cones were actually milled up, not sidetracked.*

Other operators running the Servco Junk Mill report similar results. The astonishing cutting properties of Servcoloy have completely changed thinking about down-hole milling. Why not get complete information from your nearest Servco office?

WHAT IS SERVCOLOY?*

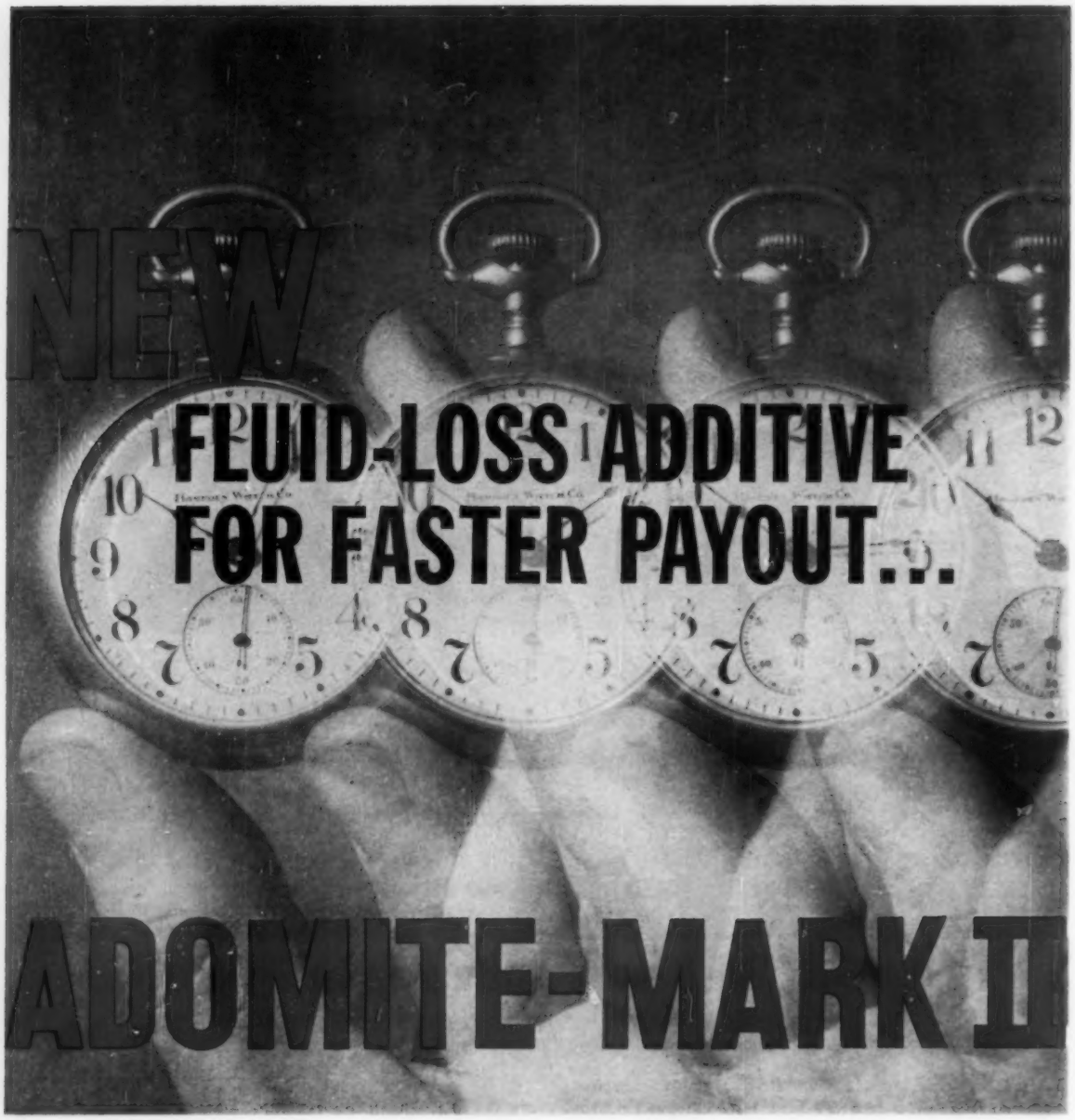
Servcoloy is a patented, hard-facing material which uses a unique method of suspending bits of carbide in a tough, elastic matrix. As the carbide cutting edges are worn away or torn from the matrix, new edges are automatically exposed. Servcoloy is now being used on Servco milling tools such as section mills, rotary shoes, taper mills, pilot mills, etc. Remedial work which formerly took days to do is now being done in hours.

SERVCO

General Offices: 2440 Cerritos Ave., Long Beach 6, California
Gulf Coast and Mid-Continent: 4850 Gasmer Street, Houston 35, Texas
Canada: 6909 - 104th Street, Edmonton, Alberta **Venezuela:** Maracaibo

Field Offices: Ventura, Bakersfield, Lafayette, Harvey, Oklahoma City

*U.S. Patent No. 2,833,638



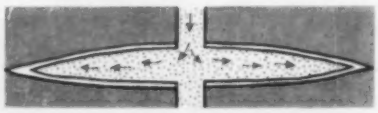
Now—from the makers of ADOMITE comes the last word in fluid-loss additives—new ADOMITE-MARK II. Regardless of the kind of fracturing oil medium you use, new ADOMITE-MARK II will give the fullest possible fluid-loss control. Result? Larger fractures and faster payouts every time!

You, along with many other producers, may want to continue to standardize on ADOMITE, proven in over 20,000 fracturing treatments to be an efficient fluid-loss control additive for a wide range of crudes.

Where unusual conditions exist and optimum fluid-loss control is imperative, ask for ADOMITE-MARK II . . . now available from your service company.

For more detailed information contact your nearest ADOMITE man:

R. T. Means, P. O. Box 431, Midland, Texas, MU 4-7411
R. W. Hughes, Oklahoma City, Okla., CEntral 2-1371
Joe M. Foster, Wichita Falls, Texas, Phone 723-8181
H. L. Thomason, Casper, Wyoming, Phone 3-3721
J. D. Hawsey, Pampa, Texas, Phone MOhawk 5-2992

ADOMITE®  *. . . fluid-loss additives*

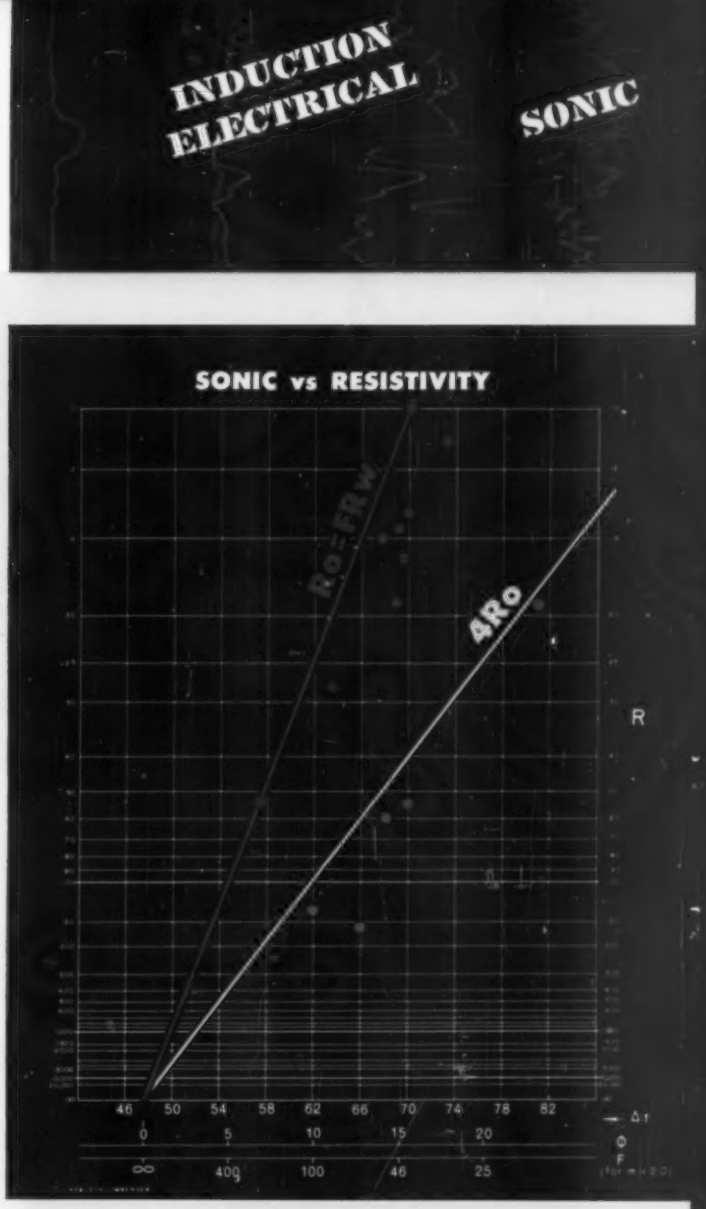
Schlumberger Sonic and Resistivity Logs Simplify Oil Finding!

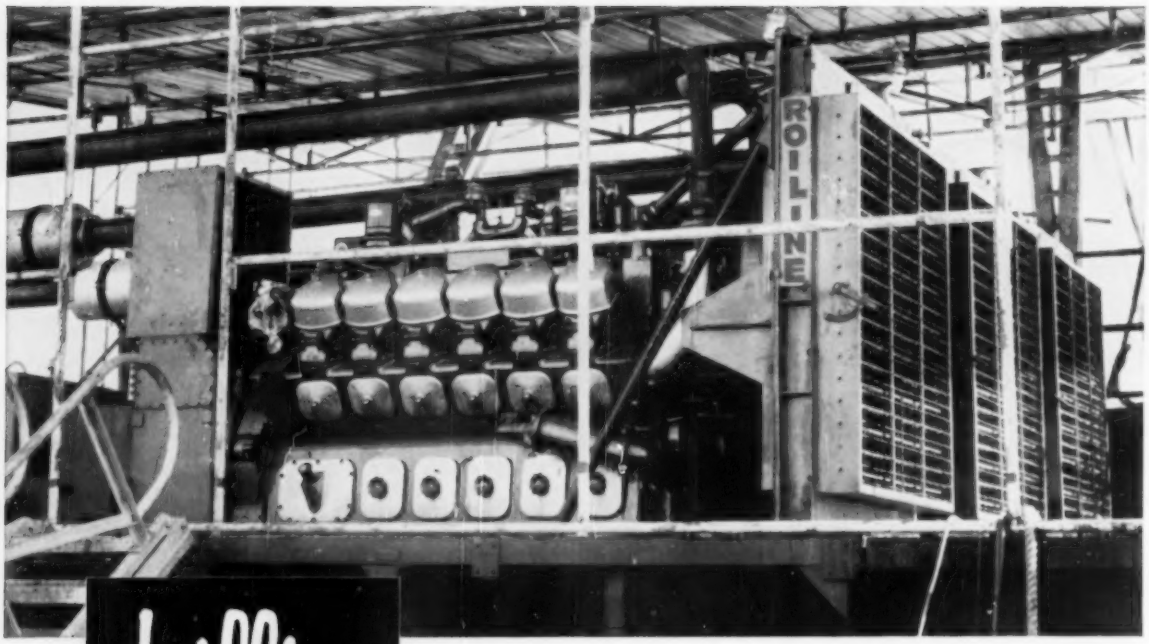
Oil and gas horizons are graphically identified by simple comparisons of Sonic and Resistivity data. These fast methods of interpretation are appropriate for well-site application. Potentially productive zones thus found can be further investigated by quantitative methods—or can be checked by sidewall cores and formation tests.

Ask a Schlumberger engineer in your area to demonstrate the benefits you can derive from Sonic and Resistivity Logs in your well program.

THE EYES OF THE OIL INDUSTRY®

SCHLUMBERGER





drilling speed and capacity with three ROILINE ENGINES

• Deep drilling power . . . lots of it . . . and fast acceleration that saves time and speeds up drilling!

Because of their V-12 cylinder design, light pistons, short radius rotating parts, and sensitive controls these Model L-3460 ROILINE Engines pick up a load fast.

Hydraulic "Zero lash" valve lifters eliminate tappet noise and adjustments and extend valve life. That means smooth, quiet engine operation and easier maintenance.

Exhaust manifold is water-cooled and integrally cast into the crankcase to provide cooler operating area and fast engine warm-up.

"Easy Flow" manifold design provides perfect fuel and air distribution to all cylinders through large individual intake ports. This advanced design manifolding . . . low friction bearings . . . low power loss to accessories—all contribute to ROILINES' remarkable economy of operation.

Send for descriptive Bulletin E-7.

WAUKESHA MOTOR COMPANY, WAUKESHA, WISCONSIN

NEW YORK TULSA LOS ANGELES

Factories — Waukesha, Wisconsin, and Clinton, Iowa

486

Model	Bore and Stroke	No. of Cyls.	Displ. Cu. In.	Max. Torque Lb./Ft. @ RPM	Brake Horsepower at Engine Speeds Indicated								
					600	800	1000	1200	1400	1600	1800	2000	2200	2400
H570	4⅛ x 4¼	8	570	490....1800		68	89	109	129	148	168	186	202	216
H844	5¼ x 4⅞	8	844	700....1200		104	133	160	185	209	232	252	263	272
F1500	6¾ x 7	6	1503	1170.... 600	134	176	214	230						
H2000	6¾ x 7	8	2004	1590.... 650	180	240	280	300						
L3000	6¾ x 7	12	3006	2420.... 650	275	360	435	460						
L3460	7¼ x 7	12	3468	2780.... 900	318	424	530	619	660 @ 1350 RPM					
L4000	7.54 x 7.5	12	4000	3280.... 800	385	500	615	706						

These are engine ratings on LP Gas . . . send for Power Chart with ratings for engines and complete power units operating on natural gas, LP Gas, and gasoline.

In the Forefront of New Drilling Advancements...

ROTATING BLOWOUT PREVENTER

You probably saw the following news item featured in recent technical articles. In it a key role was played by the Shaffer Rotating Blowout Preventer—the blowout preventer that makes possible a wide range of new savings and efficiencies in modern drilling and production techniques...

NEW DEPTH RECORD For Air-Drilling Holes Set at 18,500 FEET!

A West Texas well, bottomed at 18,500 feet, exceeded by some 2,580 feet the former record depth established by air drilling equipment. Inasmuch as the top portion of the hole was drilled with conventional fluid circulation, and the lower portion was drilled with air circulation, some interesting comparisons are available.

For example, the data shows that both the penetration rate and the bit life increased substantially with air drilling as compared to fluid drilling. However, variations in formations at the different depths make these figures interesting but not directly comparable...

During air drilling, continuous pressure control was maintained with a Shaffer Rotating Blowout Preventer. Rig report states: *"No pressure control problems were encountered while this equipment was in use."*

Average Penetration Rate:
...with fluid, 39 ft. per day.
...with air, 153 ft. per day.

Average Bit Life:
...with fluid, 68 ft. per bit.
...with air, 672 ft. per bit.*

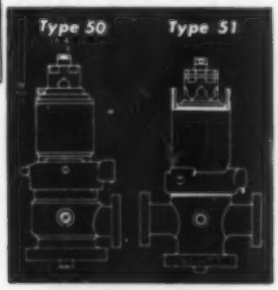
Longest Bit Run:
...with fluid, 265 ft.
...with air, 1,051 ft.*

(**Note:* The insert type bits used for air drilling cost about 5 times that of conventional rock bits, but averaged about *10* times the footage. Net difference, approximately 2 to 1!)

There is no other pressure control equipment available that will handle the range or type of applications that are routine for The Shaffer Combination Rotating Blowout Preventer and Stripper.

Available in two types...
Type 50 for drilling through 10¾" casing or larger.

Type 51 for slim-hole drilling, drilling-in, production and re-work operations.



- Here's a unit that *automatically* maintains continuous pressure seal around the drill string as long as the string is in the hole. No special drill string equipment is needed!
- The Stripper Rubber expands and contracts automatically to seal around the varying diameters of pipe, couplings, tool joints and drill collars as they pass through the unit!
- The Stripper Rubber also adjusts automatically to fit the varying *shapes* of different drill string elements—square, hexagon or octagon kellys as well as cylindrical or out-of-round shapes of pipe, couplings, tool joints and drill collars!
- The seal remains pressure-tight whether the drill string is stationary, is being rotated, or is being raised or lowered!
- The steel-reinforced Stripper Rubber is so designed that the higher the pressure the tighter the seal. Varying pressures are compensated for *automatically!*

The Shaffer Rotating Blowout Preventer is ideal for regular drilling... for drilling under pressure... for drilling with reverse circulation... and for drilling with air or gas instead of mud.

Shaffer Bulletin #1003 contains complete information on this unique blowout preventer. Your nearest Shaffer representative will gladly supply complete details. Or write direct!

37 years OF OIL TOOL LEADERSHIP

SHAFFER

HIGH PRESSURE DRILLING AND CONTROL EQUIPMENT • FISHING TOOLS THAT EXCEL

CALIFORNIA SERVICE SHOPS: Santa Fe Springs, Santa Maria, Ventura, Avenal, Bakersfield and Taft
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OKLAHOMA CITY, OKLAHOMA, Shaffer Tool Works, 6201 South Shields Boulevard
FARMINGTON, NEW MEXICO, Shaffer Tool Works, Post Office Box 1788
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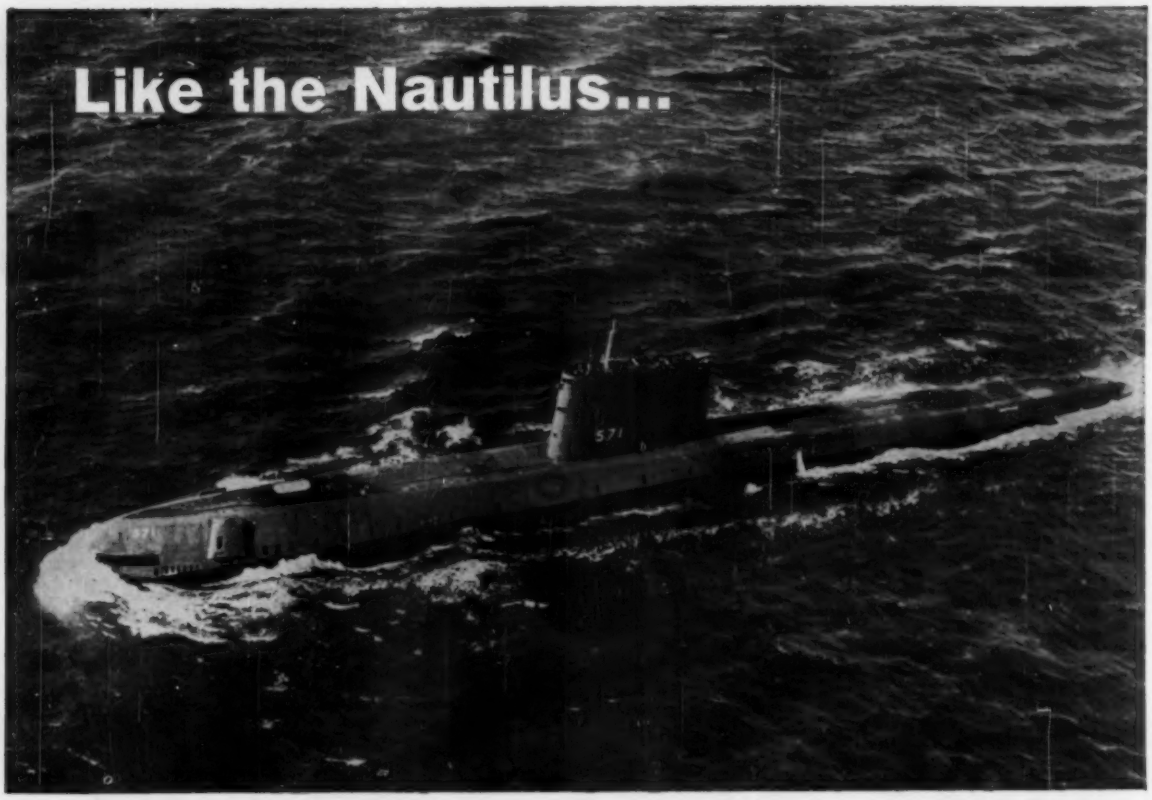
HOUMA, LOUISIANA, Shaffer Tool Works, Post Office Box 546
EXPORT SALES OFFICE: Shaffer Tool Works, 500 Fifth Avenue, New York, N.Y., U.S.A.
IN CANADA: Shaffer Western Hemisphere, Inc., 5823 103A Street, Edmonton, Alberta.



Rectorheads are *"Sealed With Steel"*

Rector pioneered the welded seal principle in casing heads . . . the same principle of welding that is used in the construction of today's atomic submarine "Nautilus," built to withstand extreme temperature variants, torque, and tremendous pressure as it cruises the ocean depths.

Rector's welded seal plus API Ring Gasket, never requires replacement or maintenance. Well or "Frac" pressure cannot be transmitted to the slips where hydraulic pressure can collapse or crush pipe. Rector casing heads are built to withstand fire, shock, freezing temperature and highest well-head pressures. The soundness and complete efficiency of application and service of the Rector welded seal has been proven in over 100,000 trouble free field installations.

RECTORHEADS are available in sizes through 20". See your Rector representative or order from your favorite supply store.

PESA

MONOGRAMMED EQUIPMENT CERTIFICATE NO. 2158

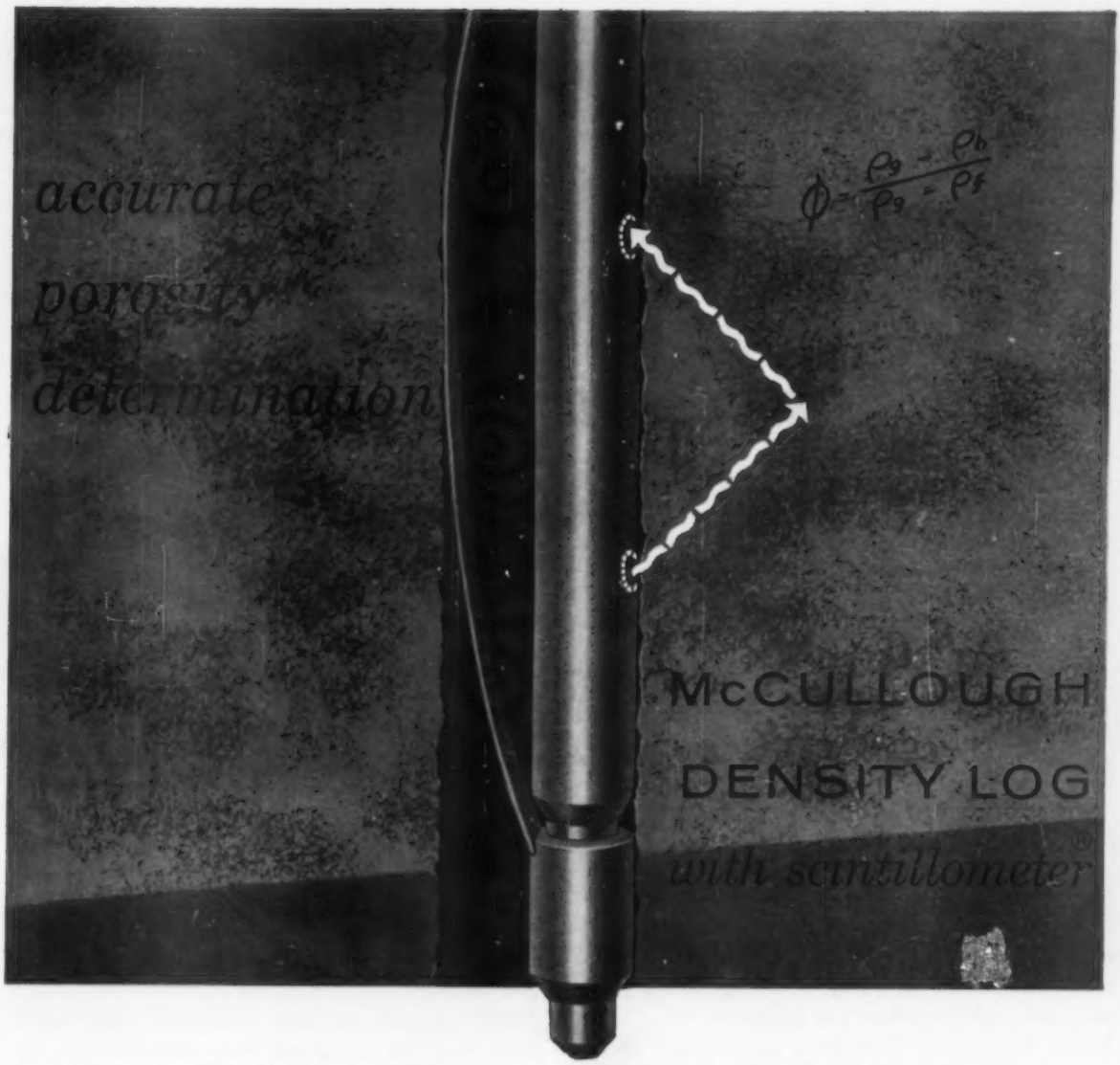
Rector

Well Equipment Co., Inc.

Making the Oil Industry Safer!

1100 North Commerce, Fort Worth, Texas
Houston Plant: 2215 Commerce Street

EXPORT REPRESENTATIVES: Continental-Emsco Co., Mid-Continent Supply Co., Oilwell Division of United States Steel Corporation



A new advancement in the field of nuclear well logging – McCullough's Density Log accurately measures the bulk density of formations. This rock density is of prime importance in the interpretation of geophysical data. Where grain density values are known, porosity can be determined with accuracy.

The McCullough Density Logger is the only tool of its type that utilizes collimation, the Scintillometer and an energy or pulse height discriminator. By this method, a beam of gamma rays is directed into the formation by the source collimator and back-scattered gamma rays are accepted by the Scintillometer collimator. The discriminator is adjusted for recording gamma rays in the energy band that reflects deep penetration. The numerical intensity of these gamma rays is directly related to the density of the formation.

Check these important features:

- Accurately calibrated in the field with a calibration block of known density.
- Absolute zero is recorded on each log and a linear count scale enables the graphic conversion of counts per second to bulk density for logs run in any well.
- Bulk density, with the grain density of the formation minerals taken into consideration, is in turn graphically converted to accurate porosity values for various types of lithology.
- Responsive to the physical properties of the formation, not its chemical properties except as they relate to density.
- Bore hole fluid and hole size changes are not reflected in the log so long as the instrument maintains adequate contact with the side of the bore hole.
- Charts are provided to compensate for the presence of mud cake in arriving at true formation density.

AVAILABILITY – This service is being made available at our district offices as rapidly as possible. Check with the McCullough representative in your locality.

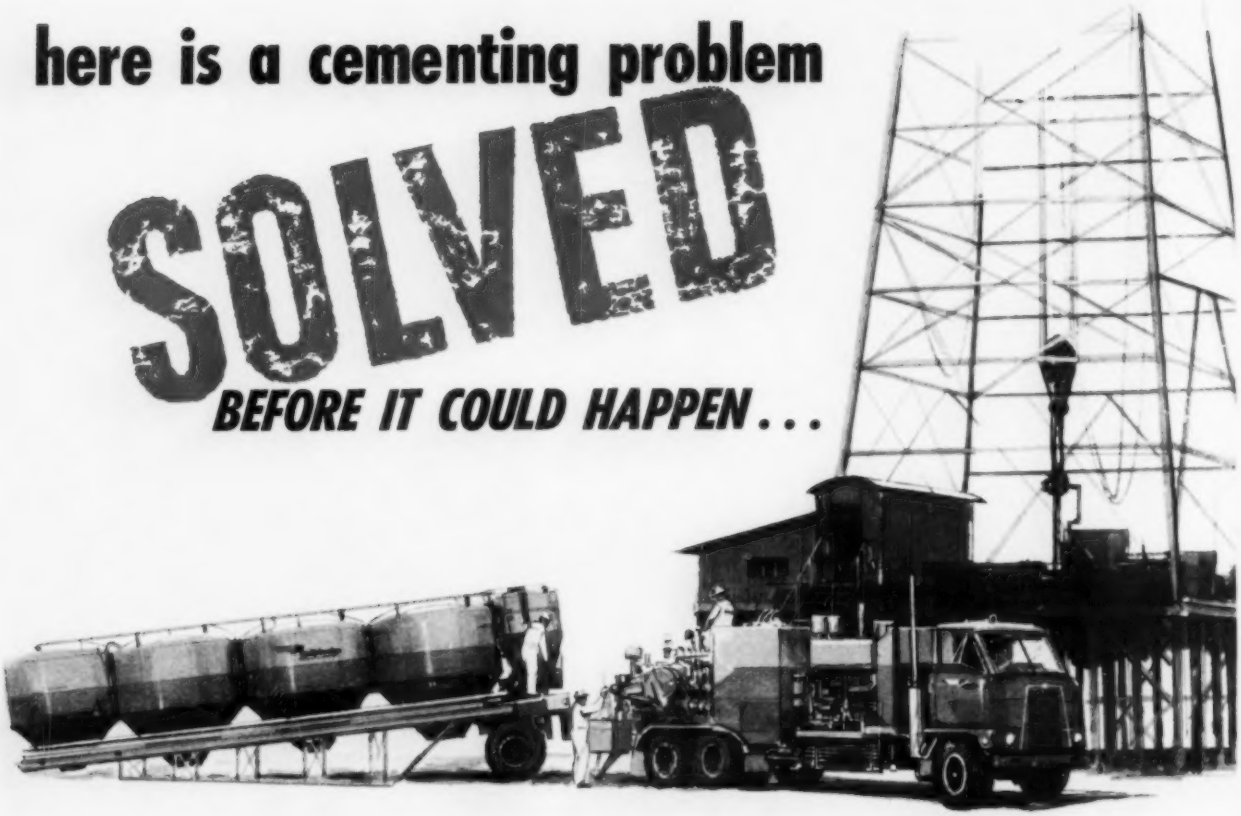
McCullough *TOOL COMPANY*

LOS ANGELES • HOUSTON • EDMONTON *Cable Address:* MACTOOL

here is a cementing problem

SOLVED

BEFORE IT COULD HAPPEN . . .



Imagine this well is yours. You're skeptical because of this formation's history . . . drilling returns, core samples – everything points to probable trouble . . . severe lost circulation during cementing. That's your problem – and here's how you handle it:

FIRST call in your Halliburton man to help select the best combination of materials and equipment you will need for the job.

The Halliburton man explains how GILSONITE is designed to lighten slurry density to help protect those weak formations from the hydrostatic head of the cement . . . *and* he points out the excellent bridging characteristics of GILSONITE which will help control any breakthrough that might occur. You then select GILSONITE to help control the circulation losses you expect.

NEXT you pick the right equipment – Halliburton Bulk Handling Equipment to provide up to 1,250 cu. ft. of cement from each unit – at speeds up to 40 sacks per minute without bothersome sack handling, spillage, or breakage. For smooth, dependable placement of the slurry, you choose Halliburton HT-400 Pump Trucks – giving you the capability to do the job *well*, and plenty of power in reserve.

SO YOU'VE SOLVED TODAY'S PROBLEM

but what about tomorrow . . . and the day after that . . . here's the answer . . .

DEPEND ON HALLIBURTON SPECIAL CEMENTS AND ADDITIVES IN ANY APPLICATION INTENDED FOR THEIR USE

for instance . . .

LATEX CEMENT – excellent for use in cementing through permeable zones. The low fluid loss qualities of Latex Cement help limit the amount of cement filterate entering into the producing strata.

POZMIX CEMENT – to provide maximum protection against corrosion, contamination and poor bonding between pipe and formation. For average depths and temperatures, Pozmix "A" and "S" provide superior qualities such as light weight slurries, low permeability and improved pumpability. Deeper, hotter wells call for Pozmix 140 which gives strength stability in well temperatures up to 400° F.

GEL-CEMENT – Halliburton HOWCOGEL helps lower fill-up costs by increasing slurry volume through the water absorption qualities of this material. This also lowers slurry weight to help protect weak formations from the load of a heavier cement column.

RADIOACTIVE CEMENT – provides you with the important ability to survey the condition of the job after completion. Accurate measure of the top of cement, location and disposition of squeeze cement, general condition of cement around specific zones, and other valuable knowledge.

RESIN-CEMENT – is widely used to help control production of unwanted water or gas. A mixture of resins, water and portland cement, this product helps seal off troublesome formation intervals by forming an impermeable bond in the zone adjacent to the plug in the well bore.

Continue to look to Halliburton for leadership

The dependability of these Halliburton products is matched by the experienced performance of the Halliburton specialists who help you use them. Ask your Halliburton Representative to recommend the *best* combination of men, materials and equipment to handle your next cementing job.

HALLIBURTON

CEMENTING SERVICES

HALLIBURTON COMPANY • DUNCAN, OKLAHOMA

OTIS PRODUCTION NEWS

Volume I, Number 2 **Otis Engineering Corporation • Dallas** *Production Equipment and Services*

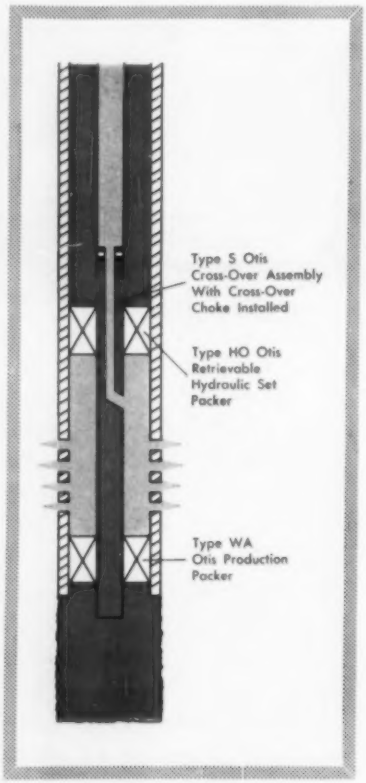
Otis 'Packaged' Well Completion Service Proves Solution To $80,000 Problem For Aggressive Oklahoma Operator

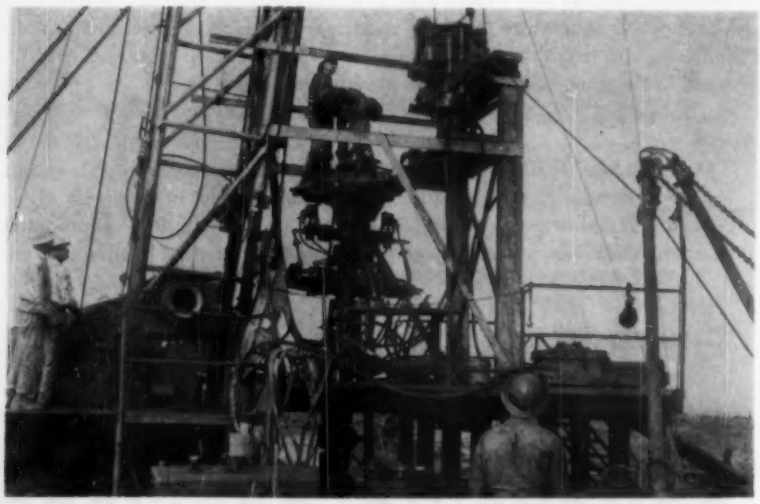
OKLAHOMA CITY — Otis well completion specialists from the Lindsay division have performed a slightly different, but basically sound, technique of completing a number of single string, dual producers for one of Oklahoma's most progressive independent operators. The wells are located in a new field being developed by this producer.The technique is that of snubbing all downhole production equipment into each well under pressure instead of killing the well. This technique has solved a problem which cost this operator some $80,000 on one well he drilled and completed in this field by another method.

The costly problem well potentialed 400 B.O.P.D. when originally swabbed in following a down-casing well stimulation treatment. Faced with not having production equipment in the well for either zone, and a 600 P.S.I. shut-in pressure, the operator decided to kill the well with a heavy lease oil before running packers and tubing. After necessary production equipment had been installed all attempts to swab the well in again failed, as did numerous special zone-stimulation fluids and treatments during the following 2½ months. When the well was finally brought in for the second time, its daily potential was considerably less than the initial 400 B.O.P.D. All told, the well owners counted a staggering $80,000 spent to get production back. Since that time Otis has been engineering the completions for this operator and snubbing all equipment into the hole under pressure. The cost of Otis' Snubbing Service has averaged less than $2,000 per well.

The completion equipment consists of a Type WA Otis Production Packer, a Type HO Otis Hydraulic-Set Packer, and a Type S Otis Cross-Over Assembly. The WA packer is a permanent-type, wire line set production packer which is used to isolate the two producing zones. The top packer is the Type HO Otis Hydraulic-Set Tubing Retrievable Packer, which is set by pressuring up on the tubing after first landing a special setting tool in the cross-over assembly made up in the packer.

In this type of installation the top packer is tested by bleeding off pressure in the casing. As engineered by Otis, this completion permits the lower zone to be produced through the annulus and the upper through the tubing — saving the cost of a second string of tubing and a dual packer — and at the same time affords a full-opening tubing string for obtaining bottom hole pressures, etc. The flow pattern of the two zones may be reversed if desired simply by changing chokes in the cross-over assembly.





Shown here are trained Otis service specialists rigging up to snub production equipment into a well under pressure. All equipment is hydraulically operated and well pressure is under control throughout the entire operation.

The technique of snubbing pipe and downhole production equipment in and out of oil and gas wells under pressure was developed by Otis 32 years ago. It has proved its economic advantages — as in the case of this operator — time and time again. The work is done by trained Otis specialists with unparalled experience in this type of work. For a detailed description of Otis' Snubbing Service, and the packers and cross-over equipment used in these wells — or for help with any of your well completion problems, call the Otis office nearest you or write Otis, Dept. 2-P, Box 35206, Dallas 35, Texas. Experienced Otis specialists are ready and anxious to provide you with a "packaged" well completion service.

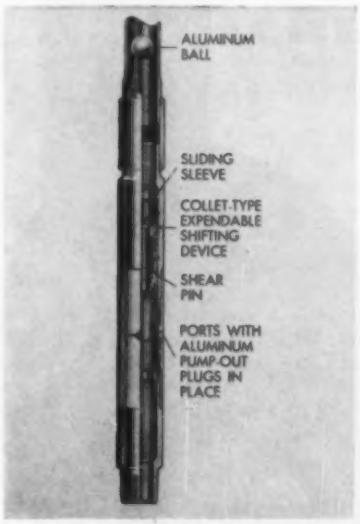
©1960 O.E.C.

Better Production Tools Through Research

New Otis Tool Provides Additional Blowout Protection—Cuts Completion Costs

BELLE CHASSE — Operators in this area are using a new version of the Type A Otis Sliding Side-Door to complete their high pressure wells with greater safety and economy. This tool permits them to run high differential type drillable packers and nipple up the tree before unloading the well during completion operations. This makes possible a completion technique which allows the operator to keep his well under control throughout the entire operation. It also eliminates the need of having a wire line service unit on location and the problems encountered when performing wire line work in heavily weighted fluids.

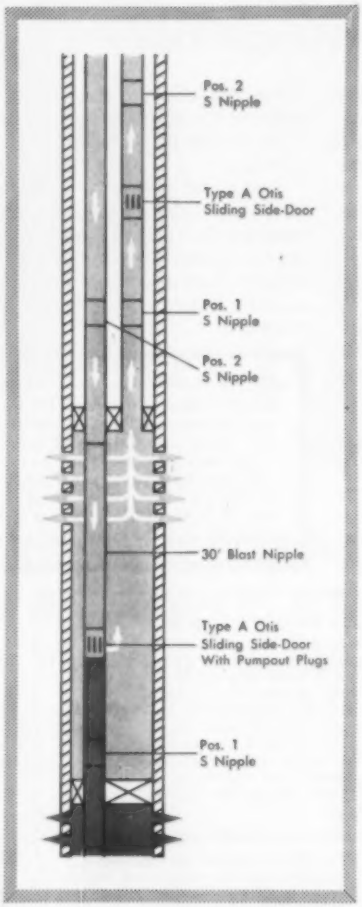
This new version of the Sliding Side-Door® is designed to be run into the well on the tubing with the sleeve opened. Tapered aluminum plugs inserted in the ports of the tool's outer mandrel serve to prevent communication from the casing annulus to the tubing until the well is to be circulated. A special collet type expendable shifting device is located in the upper recesses of the tool's sliding sleeve. This shifting device is designed to catch an aluminum ball or drop plug that is pumped down to close the side-door. (See illustration below.)



Type A Otis Sliding Side-Door with pump out plugs and expendable shifting tool in place.

The technique made possible through use of this new tool is both simple and sure. One of several ways the tool is being used is as shown in the accompanying schematic. The new model Sliding Side-Door, with special pump out plugs in the ports, is made up in the long string and located between the two packers. A standard Sliding Side-Door is located in the short string above the top packer for use at a later date. With this equipment in the well, packers may be tested by pressuring up on the short string. Blowout preventers are then removed and the tree installed with mud in the hole.

Once all provisions have been made to bring in the well, pressure is applied to the long string to dislodge the pump out


Pos. 2 S Nipple
Type A Otis Sliding Side-Door
Pos. 1 S Nipple
Pos. 2 S Nipple
30° Blast Nipple
Type A Otis Sliding Side-Door With Pumpout Plugs
Pos. 1 S Nipple

plugs and mud is circulated out of the well through the short string. Approximately 400 pounds' differential pressure is all that is required to dislodge the plugs. Once mud has been displaced, the sleeve in the Sliding Side-Door may be shifted to its closed position by pumping down an aluminum ball or drop plug. The design of the expendable shifting mechanism in the Sliding Side-Door is such that when the sleeve reaches its fully closed position the collets on the expendable shifting tool release and the shifting device can be pumped out of the bottom of the tubing. After the Sliding Side-Door has been closed, it may be reopened for circulation or production at any future date by standard wire line methods. In the closed position, both V-type packing and O-rings act to provide a positive seal between the sleeve and outer mandrel of the tool.

The Otis Sliding Side-Door, with special pump out plugs, was designed and built to help operators reduce their costs when completing wells offshore and in inland water locations. However, the tool has proven so successful in this usage that several major companies have adopted both this new tool and completion technique as a standard operating procedure for all their high pressure wells.

Perhaps you are faced with completion and downhole production problems with which your local Otis specialists can help you. If so, call them today. For more information on the new Type A Otis Sliding Side-Door with pump out plugs or for help with any completion problem, call the Otis Office nearest you or write Otis, Dept. 2-P, Box 35206, Dallas 35, Texas. You'll find experienced Otis well completion specialists ready to help you — anxious to serve you.

New Otis Catalog Serves As Well Completion and Wire Line Service Guide

A new 116-page multicolored catalog of production equipment and services has just been published by Otis Engineering Corporation and is available upon request.

The new catalog contains drawings, operating diagrams, installation schematics, descriptive material, and complete dimensional data on more than a hundred different Otis tools — some of which have never been cataloged before. The catalog is divided into six sections to help the user find any piece of Otis equipment, or any one of their special services, easily and quickly. The sections cover Safety Equipment, Gas Lift Equipment, Completion Equipment, Post-Completion Equipment, Special Services, and Service Tools. Each section contains a concise preface describing the different types of equipment or services covered by that section and where and when the equipment or service should be used. The catalog has an index by sections, and is indexed and cross-indexed alphabetically by tool.

This new catalog will serve as the Otis section of the 24th (1960-61) Edition of The Composite Catalog, however those interested in obtaining a copy for their own personal use may do so by writing Otis Engineering Corporation, Dept. 2-P, Box 35206, Dallas 35, Texas.

OTIS

Engineering Corporation

General Offices:

6612 Denton Drive • Dallas, Texas

Baker's New Snap-Set Duals

—the packers that are bringing single-zone control and simplicity to dual completions

A Baker dual-string completion approaches the control and simplicity (and the flexibility) of a single-zone completion. What makes this possible? Mainly the development of better upper retrievable packers—Baker's new Snap-Set Dual Packers. Operators all across the country are commenting on their impressive performance.

What makes a good dual-string packer? Several things, starting with the ability to (a) set and unset readily and repeatedly; (b) pack off and retrieve easily; (c) hold a dependable packoff even when pressures and temperatures are high.

Do Baker's new dual packers do these things? They do. This is easy to understand when you consider Baker's vast experience with high performance retrievable squeeze packers. The Baker Full-Bore Cementer, for instance, has seen action in thousands of successful high pressure cementing, frac, and testing operations. This squeeze packer experience has made important contributions to the design of these new dual production packers.

That's only a brief look at the story of these remarkable packers. A few more of the interesting facts are spelled out by the pictures and text below. For a complete fill-in on Baker snap-set duals and the hookups they're used in, consult Baker's field staffs and send for literature.

FACTS ON PLANNING DUAL-STRING COMPLETIONS

Baker field staffs have all the latest facts and figures on Baker's intensive continuing study of dual-string completions. They will welcome your inquiries. We will also be glad to send you the latest literature. Please write Baker Oil Tools, Inc., P.O. Box 2274, Terminal Annex, Los Angeles 54, California.

TWO BASIC MODELS. Model J (Product 756-J) is long-string set. Model K (Product 756-K) is short-string set. Both come with or without hold-down buttons (double or single grip). The pictures show single-grip Model J.

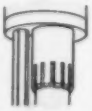
WHAT MAKES A GOOD DUAL PACKER?

The text above tells some of the things that are important. Here are a few more of the facts, starting with big unrestricted bores. Big bores are important because they permit you to run instruments and workover tools. These are probably the largest bores it's possible to design into a dual packer. For instance, a Baker dual packer for 7" casing is full-opening for two strings of 2⅜" tubing.

POSITIVE PACKOFF AND RELEASE

This three-element packing element design achieves a positive and lasting packoff with minimum set-down weight. It also simplifies release when you want to reposition or retrieve. What makes this possible is that the design prevents packing element extrusion without using the conventional metallic back-up rings that sometimes stick to the casing and defeat retrievability.

WHY SNAP-SETTING IS IMPORTANT



This simple snap-latch is what makes a Baker dual packer so easy to set and unset repeatedly. There are no one-shot shear pins. There's no ball dropping, no pressuring, no rotation. Just set down minimum weight to set packer, and pick up to release. This simplifies spacing out and enables you to test packers before displacement.

YOU CAN DISPLACE WHILE FLANGED UP

Using a side door completion valve, or sleeve valve, or other method, you can displace mud and wash in both zones with well head flanged up and under complete control.

BAKER

SNAP-SET DUAL PACKERS

BAKER OIL TOOLS, INC. HOUSTON • LOS ANGELES • NEW YORK

FIG. 1. The hammer drill (with drill-collar safety clamp in place) has just been given an operational test and is ready to run in the hole.

THE HAMMER DRILL shown in Fig. 1 has just been given a running test before starting the trip into the hole. It is in an air or gas operated tool having a hammer which strikes the anvil and bit 1800 blows per min.[1] This impact combined with normal rotation and drill collar load has produced some remarkable increases in drilling performance.

Is bit life really longer when used with a hammer drill? The answer now is a definite yes. Many bits have been run on the hammer drill and compared with bits used in conventional air rotary drilling. In most of the runs, the bit life on the hammer drill was longer, in some the life was the same, and almost none was it less. By May 15, 1960, 150 bits had been used on the hammer drill in 40 wells drilling over 55,000 ft. Up to 31,490 ft of hammer-drill hole using 71 bits had been drilled that could be compared with 18,675 ft of conventional air rotary drilling. This was done in 20 wells.

PERCUSSION DRILLING TOOL INCREASES BIT FOOTAGE

Drilling over 55,000 ft of comparable test hole, hammer drill gave bit footage 1.3 times that of conventional air-rotary drilling

WALTER E. LILJESTRAND, *Mission Manufacturing Company, Houston, Texas*

FIG. 2. 4¾-in. air-rotary bit drilled 300 ft of limestone. Compare with bit No. 3 (Fig. 3).

FIG. 3. 4¾-in. hammer-drill bit drilled 426 ft of limestone, 1.4 times as far as bit No. 2 (Fig. 2).

The average bit footage with the hammer drill was 445 ft compared with 340 ft of rotary-drilled hole, or 1.3 times as far. This ratio is conservatively low because in many instances in early drilling experiences, the bits were pulled and changed for reasons other than bit wear. Some times these green bits were rerun to give long useful life. Experience since this tabulation continues to show better bit footage.

On what basis can bit life be compared to give a true comparison between two different drilling methods? Characteristics of a bit run are feet drilled and hours per bit. A related influence is the time required to make a trip to change the bit. A thorough analysis of a bit run also requires consideration of the cost of the bit and hourly rig cost. Cost per foot can be calculated, but this requires more time and work than is usually available. A simple analysis on the other hand can be made by comparing the bit life to only one characteristic of the run — feet drilled per bit. When footage increases, the cost of bit and trip per foot of hole decreases.

The other bit characteristic, hours

FIG. 4. Conventional air-rotary bit drilled 127 ft in sand and shale in comparative test with bit No. 5 (Fig. 5).

FIG. 5. Hammer-drill bit drilled 220 ft in sand and shale, 1.7 times as far with less wear than bit No. 4.

per bit, should not be used by itself to rate bit life. An increase of hours alone increases the cost per foot of hole. These factors say that the operator should want, first, to drill more footage and, second, to drill faster to get the lowest cost. Hours on bottom should never be used alone to compare bit performance.

Cost per Foot

Consider two runs in the same formation where the bit footage was the same, but due to different drilling methods one bit lasted twice as many hours as the other.

Bit No.	Footage	Hours	Cost/ft*
1	300	10	$4.50
2	300	20	$7.20

The first impression might be that bit No. 2 which lasted longer was the best, but the increased drilling time makes it cost 60 percent more.

*Cost per foot of hole was calculated using the following estimates: Rig cost $80 per hr; bit cost $200; trip time 4 hr; fixed costs of rig were neglected as they would not greatly influence these cost comparisons.

$$\text{Cost/foot} = \frac{\text{Hr/bit} \times \text{rig cost/hr}}{\text{footage/bit}} + \frac{\text{trip time} \times \text{rig cost/hr} + \text{bit cost}}{\text{footage/bit}}$$

Now consider the case where, in the same formation, the bit life in hours was the same, but due to different drilling methods one bit drilled twice as many feet as the other.

Bit No.	Footage	Hours	Cost/ft
1	300	10	$4.50
3	600	10	$2.25

Here one can correctly assume that bit No. 3 which drilled the most footage was best. In the example given, doubling the footage reduces the cost to half.

In the third case, footage and hours are increased in proportion, giving a constant drilling rate.

Bit No.	Footage	Hours	Cost/ft
1	300	10	$4.50
4	600	20	$3.60

The bits are actually about the same quality. The cost saving resulting from increased footage is partially offset by the longer time of the run. Net saving is 20 percent and this diminishes for runs of greater length.

These examples show that a better run is basically characterized by increased bit footage. Another indication of a better run is increased drilling rate. An increase of hours is basically an indication of a poor run. If hours per bit increase, there must be some compensation to keep cost per foot from rising.

FIG. 6. Air-rotary bit drilled 221 ft in 40-percent sand-shale in tests with bit No. 7.

FIG. 7. Hammer-drill bit drilled 199 ft in 55-percent sand-shale and shows almost no wear compared to bit No. 6.

Finger print experts say that no two finger prints are alike. It is quite possible, also, that no two bits have ever performed alike. Usually the differences in performance seen on the bit record are very great, even with the same drilling method, rpm, and weight. Formation structure, hardness, abrasiveness, dip, and depth are greatly variable causing large changes in bit performance. However, by searching bit and geology records, it is possible to find a few examples where formation variations have no influence on comparative bit runs. It is necessary to find field runs where drilling methods alone are the variable, so that the maximum performance increase can be learned.

Field Experience

The first experiences on comparative bit footage with the hammer drill and the conventional air rotary were obtained in a field test made on a laboratory basis.[2] A truck-mounted shot-hole rig was used to drill test holes in an outcrop of Oolagah limestone. Drilling conditions were carefully controlled and frequent checks of bits were made. Each bit was run to destruction which usually occurred when the bit was very dull. Photographs of two of the test bits were made just a few feet before final failure.

The air rotary bit in Fig. 2 drilled 300 ft. The hammer drill bit in Fig. 3 drilled 420 ft, or 1.4 times as far. Tooth wear shows that the footage ratio would have been much greater than 1.4 if it had been worn like the other. However, this was a standard bit and the bearing-retaining pins came out. Modifications in the pin and welding used now prevent this.

In addition to this footage advantage, the hammer drill drilled 65.5 ft per hr, compared to 37.5 ft per hr, or 75 percent faster. This early discovery of increased bit footage has been confirmed over and over in field experiences.

Field experiences listed below were selected from logs that definitely show the test formations were uniform, or slightly harder for the hammer drill. Wear and footage differences should therefore be due entirely to the two different drilling methods.

The 8¾-in. bit shown in Fig. 4 was used near Bandera, Texas, with conventional air to drill 127 ft. Fig. 5 shows the bit used on the hammer drill in the same formation. It drilled 220 ft, or 1.7 times as far and shows less wear on the teeth. It drilled 29 ft per hr against 6.6 ft per hr, or 4.4 times as fast.

The 8¾-in. bits in Fig. 6 and 7 are shown even though the hammer drill bit in Fig. 7 was pulled prematurely. It

drilled 55 percent sand-shale formation compared to 40 percent sand-shale for the conventional air bit in Fig. 6. It is almost as sharp as new while the other is very dull.

The bits in Fig. 8, 9, 10, and 11 were not worn out, but show wear and footage comparisons. They were run as needed and pulled when plugged with water and cuttings. Table 1 shows the main data.

In spite of the mixture of data in Table 1, a number of important conclusions can be made. First, the Run No. column shows that air drilling in II, IV, and VI was with low penetration rate and alternated with hammer drill Run No. III and V. Comparing bit 8 with bit 10, the hammer drill bit 10 drilled 2.4 times as far in slightly less time and shows less wear on the teeth. Bit 9 compared to bit 11 drilled half of its life in hours with air, but most of its footage with hammer drill. Its total footage is 1.4 times as far as air bit 11.

FIG. 9. 115 total ft—22 air-rotary and 93 hammer-drill—were drilled with this bit. Total is 1.4 times as far as bit No. 11.

FIG. 11. This bit drilled 83 ft with air-rotary with medium wear. Compare with bit No. 9.

FIG. 8. Bit drilled 87 ft with air-rotary with medium wear under conditions similar to those for bit No. 10.

FIG. 10. Combined footage of 201 ft hammer-drill and 6 ft air-rotary drilled with bit No. 10 was 2.4 times as far as bit No. 8.

TABLE 1.

Bit No. (Fig. No.)	Run No.	Method*	Footage	Hours	Ft/hr	Wt. on bit	RPM	Wear
8	I	C.A.R.	87	12.6	6.9	3M	65	Medium
9	II	C.A.R.	22	6.7	3.3	11-14M	65	Slight
	V	HD	93	7.0	13.2	6M	45	Medium
10	III	HD	201	12.3	16.4	3M	55	
	IV	C.A.R.	6	2.1	2.8	6M	60	Light
11	VI	C.A.R.	83	9.0	9.2	10M	55	Medium

*C.A.R. — Conventional Air Rotary. HD — Hammer Drill

TABLE 2.

Fig. No.	Method	Depth out	Footage	Hours	Ft/Hr	Weight on bit 1000 lb	RPM	Formation	Location
2	C.A.R.	—	300	8.0	37.5	7.3	180	Limestone	Tulsa
3	HD	—	426	6.6	65.5	10	60	Limestone	Tulsa
4	C.A.R.	2223	127	19.5	6.5	4/8	65	1% sand-shale	Bandera, Texas
5	HD	3620	220	7.5	29	2/4	35	1.4% sand-shale	Bandera, Texas
6	C.A.R.	2444	221	30.5	7.3	6/15	65	40% sand-shale	Bandera, Texas
7	HD	3819	199	11.7	17.0	2/6	40	55% sand-shale	Bandera, Texas
8 thru 11—See Table 1.								Sand-shale Sand streaks Siltstone	Johnson County, Arkansas
	C.A.R.	4076	26	5.0	5	8/10"	70	Shale-sand	Pope County, Arkansas
Photograph not available—Reported average dull bit									
12	HD	4177	101	6.5	17	3/10	35	First 44 ft very hard sand, balance shale with hard sand stringers.	Pope County, Arkansas
	HD	4493	316	11.5	27	3/10	35	Shale-sand	Pope Cty., Ark.
	C.A.R.	4422	29	3.2	9	—	—	Shale-sand	Pope Cty, Arkansas
Photographs not available—Last bit reported average dull.									
14	C.A.R.	1987	34	1.6	21	5	55	Sand-shale	Johnson County, Arkansas
15	HD	2100	113	4.9	23	4	50	Sand streaks	
16	C.A.R.	2130	30	3.5	8.6	4	50		

In another well drilling at over 4000 ft, conventional air drilling was used on a bit which drilled through shale and sand for 26 ft in 5 hr. It was reported to be average dull. The bit shown in Fig. 12 was run next on the hammer drill. The first 44 ft was in very hard sand and the balance was shale with hard sand stringers for a total of 101 ft in 6½ hr. Footage drilled was 4 times as far as conventional air and Fig. 12 shows it to be in better than "average dull" condition.

In the same well, two more runs were made in a formation reported to be shale-sand. The hammer drill bit was run first and drilled 316 ft, 11 times as far as the air rotary bit which drilled 29 ft. And was reported to be average dull. Data for these runs are shown in Table 2 following data for bit in Fig. 12.

In another well, the 9⅞-in. bits shown in Fig. 14, 15, and 16 were used in the order shown for conventional air, hammer drilling, and then conventional air again. The bit in Fig. 14 drilled 34 ft in 2 hr and the bit in Fig. 16 drilled 30 ft in 3¾ hr. The hammer drill bit run of 113 ft in 5½ hr is 3.3 times as far as the average of the other two runs. This bit also showed less wear on the teeth and less loss of gage.

From these examples, it is expected that bit footage on the hammer drill compared to conventional air should be increased 1.3 to 4 times.

Hammer Drill Bits

The rock bit for the hammer drill is standard in one sense and special in

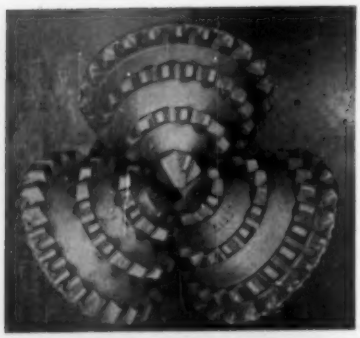


FIG. 12. Hammer-drill bit drilled 4.0 times as far in harder formation than the air-rotary bit before it which was reported to be average dull.

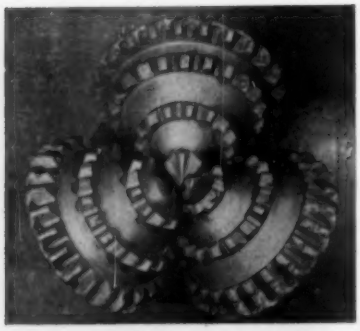


FIG. 14. 9⅞-in. bit was used with air-rotary to drill 34 ft in 2 hr. Compare with bit No. 15.

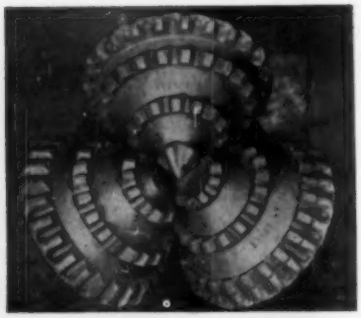


FIG. 15. This hammer-drill bit cut 113 ft in 5½ hr, approximately 3.3 times as far as bit No. 14 and No. 16.

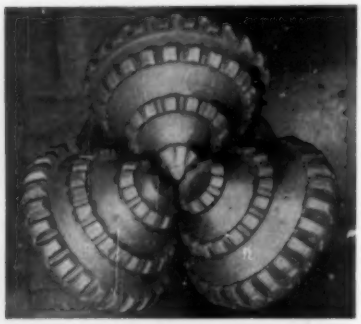


FIG. 16. Final bit was used with conventional air-rotary to drill 30 ft in 3¾ hr.

another. The cones and tooth form for use on the hammer drill are the same as for conventional air drilling. The early experimental testing on the Oolagah limestone showed that two minor modifications in the design of the bit were desirable. The seam weld holding the legs of the bit body together was made stronger to resist the tendency to split upward from the bottom. The ball-retaining plug for the bearing was more firmly installed in the journal and then welded securely.

The hammer drill will run more efficiently if the bit produces a minimum pressure drop through the nozzle. The lowest back pressure is obtained by torch cutting an opening in the body equal to the full flow area through the bit pin.

It is a proven fact that additional footage is obtained from bits on a hammer drill. There has not been enough basic research yet to know the entire reason for this. One of the factors that probably contributes to the increase is the size of the cuttings produced with the hammer drill. The suddenness of the hammer blow with the drill collar load fractures the bottom of the hole producing cuttings much larger than with conventional air drilling. If the tooth wear for each contact on the bottom of the hole is the same for either drilling method, the one with the larger cuttings will have proportionately more footage life. In order to retain this advantage fully, sufficient air volume must be used to blow these cuttings out of the hole to avoid redrilling.

Drilling Techniques

Rotary speeds of 40 to 60 rpm are fast enough to move the cutter to a new cutting position between successive hammer blows. With a rotary speed of 60 rpm, the gage cutter of a 9-in. bit will roll about 1-in. between blows.

Almost any drill collar load can be used that is required by the hole conditions. Load on the bit is essentially the drill collar load. The time duration of hammer blow is very short so that, most of the time, bit is carrying only the drill collar load. On the other hand, the drilling effect with the hammer may be 2 to 5 times that of the drill collars alone, so greater footage with the bit is expected.

In some areas hard-tooth bits are used on a hammer drill to get lower cost per foot than carbide insert bits on conventional air rotary. The footage of the hard tooth bit is expected to be less, say from half to equal that of the carbide insert bit. This reduction is more than offset by a drilling rate increase of 2 to 6 times and a bit cost reduction of 80 percent. Carbide insert bits have been used with advantage on the hammer drill but it is not likely that the percent gain will ever be as large as with steel tooth bits.

Holding gage is a problem in some formations. Reaming with the hammer drill in an under-gage air rotary hole has been done. Rotational speed should be high. If the shoulder formed with the bit is wide enough to give good support to the cutter, the hammer drill will ream at a very high rate.

A very important problem on a rig is when to pull the bit. With conventional drilling, it is known that the drilling rate decreases to approximately ⅓ as the teeth wear from sharp to dull. A drilling rate recorder will easily detect this change of sharpness if the formation is uniform. Experience combined with drilling rate and rotary torque measurements and a study of formation samples, may indicate when a conventional bit is worn out. The use of a hammer drill only complicates this problem because in many cases it has been noticed that the drilling rate does not fall off so much when the bit gets dull. Close attention should be given to the bit footage and drilling rate so that full advantage of this drilling method can be obtained.

ABOUT THE AUTHOR

WALTER E. LILJESTRAND is Chief Research Engineer for Mission Manufacturing Company at Houston, Texas. He received a BS degree in Mechanical Engineering from Rice Institute in 1937. Following graduation, he worked in Product Development at Mission for four years. On joining the Navy, he became an instructor and administrative officer in the Diesel Training Program at Pennsylvania State College and North Carolina State College. At the end of the war he returned to Mission to do research work on centrifugal pumps, mud pumps, and the hammer drill. He is a member of the API, SESA, SAE, Tau Beta Pi, delegate to AWHEM and Hydraulic Institute, and the Air/Gas Drilling Committee of AADC.

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2. Howard, G. C., Vincent, R. P., and Wilder, L. B., "Development and Field Use of a High Frequency Gas Operated Rotary Percussion Drilling Tool," Society of Petroleum Engineers of AIME, Paper No. 1286-G, October 4-7, 1959.

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Natural guar gum . . .

LOW-SOLIDS MUD RESISTS CONTAMINATION

Modified guar gum makes a low-solids mud in salt water which exhibits properties similar to NaCMC-fresh water fluids

H. E. Mallory
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THE DRILLING INDUSTRY has been able to give the petroleum producer lower overall costs in recent years because of increased knowledge of the variables which affect rates of penetration.

Through research and field experimentation, the contractor has improved penetration rates by improved hydraulic programs and carefully planned mud programs. Field results indicate that overall costs can be reduced and more accurate geological information obtained by planning ahead.

It has been accepted by the drilling industry that low solids muds used in conjunction with proper drill collar weights, rpm, and hydraulics offer better rates of penetration. Low solids fresh water muds contain minimum amounts of bentonites and low specific gravity drill solids combined with high or low viscosity grades of sodium carboxymethylcellulose (NaCMC).

Recognizing the distinct advantages that could be gained by making a low solids mud in salt or highly contaminated water that would offer all of the advantages gained by NaCMC in fresh water, we have, for the past three years, engaged in a development program to produce a colloid that would afford all of these desirable qualities.

Requirements for Colloid

It was determined that there was a need for a colloid which would have the following performance characteristics:

1. Produce desirable viscosity with low concentration in both salt and fresh waters.
2. Be inert to contamination from soluble salts.
3. Be readily soluble in cold water.
4. Have good film-forming ability.
5. Be temperature stable.
6. Be bacteriostatic.
7. Be compatible with surfactants.
8. React readily to organic dispersants.
9. Retain original viscometric character under shear.
10. Have ability to reduce fluid loss in the presence of minimum solids.
11. Have the intrinsic ability to afford removal from facies of porous formation by chemical treatment.
12. Retard wetting of water-sensitive formations.
13. Be competitive with colloids presently used in building viscosity and reducing fluid loss in saline as well as fresh-water systems.

These requirements readily narrow the field of selection from the materials available. The natural gums offer what appear to be the best prospects in this class. The guar gum meets more of the basic requirements, and appears to lend itself to modification to meet those requirements it doesn't fulfill in its natural form.

Chemical Composition of Gum

Guar gum and NaCMC are both polysaccharide materials. The guar molecule configuration contains many sites which have adjacent cis hydroxyl groups (Fig. 1). This feature enables guar to bond water more efficiently and to exhibit pseudoplastic behavior in water. NaCMC does not contain the cis configuration as it is a polymer of glucose units. It therefore behaves differently with respect to water absorption and properties resulting from its solution.

Hydration of both guar and NaCMC is believed to proceed by the process of hydrogen bonding. Bridges of water held together by hydrogen bonds are formed. If many hydroxyl groups are available, many such bridges can result and water will be readily absorbed and bonded. Both guar and NaCMC are structurally rigid molecules with many available hydroxyl groups and offer initially a large effective surface for water bonding. Carboxymethylation of cellulose has resulted in substitution of other groups which provide more rapid and greater water solubility. These acid groups are sensitive to salt.

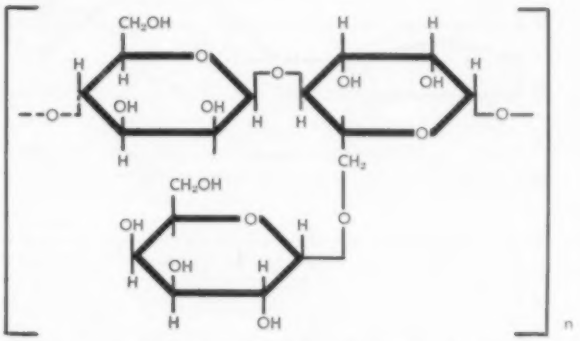


FIG. 1. Guar gum molecule, a polysaccharide, bonds water efficiently and exhibits pseudoplastic behavior in water.

Field Performance

Studies made in the last three years in the lab and field have led to several modifications of guar gum. These modifications have made the gum meet most of the required characteristics. It is now available for field use under the name of Lo-Loss.

Two wells in Terry County, Texas, one using an inhibited fresh water and the other a brine water saturated with sodium, calcium, and magnesium salts, best illustrate the versatility of guar gum in formulating drilling fluids giving maximum viscosities with minimum yield points, affording excellent fluid loss control while having less than 2 percent solids.

Fresh water. To a 1100-bbl oil-in-fresh-water emulsion system being used in Terry County, the following materials were added:

1100 lb guar gum

THE AUTHORS

Left to right: W. E. Holman, Great Western Drilling Company; H. E. Mallory, Kendavis Industries, Inc.; R. J. Duran, Loffland Brothers Company.

12 bbl diesel oil
24 gal non-ionic emulsifier
The fluid properties before and after this addition were:

	Base Fluid	*Conditioned Fluid*
Mud weight — lb/gal	8.4	8.4
Funnel viscosity — sec/qt	29	40
Apparent viscosity — cp	2	14
Plastic viscosity — cp	2	8
Yield point — lb/100 sq ft	0	9
Initial gel — lb/100 sq ft	0	0
10 minute gel — lb/100 sq ft	0	0
Water loss — cc	74	5.4
Filter cake — 1/32 in.	1	film
pH	6	7
Ca and Mg as $CaCO_3$ — epm	48	48
Chloride ion — ppm	1500	1500
Oil—% by volume	7	8.5
Solids—% by volume	1.5	1.5

Two days after conditioning the mud, 1.5 lb per bbl of an organic deflocculant was added which seemed to stabilize the viscosity as no more dispersant was needed. Daily maintenance was 50 lb of gum, 5 gal of non-ionic emulsifier and 5 bbl of diesel oil. Fig. 2 shows the characteristics that were maintained and the daily consumption of materials. Maximum bottom-hole temperature in this well was 157 F at 10,022 ft.

Salt water. To a salt water native mud being used in Terry

Daily Consumption and Fluid Properties—Fresh Water

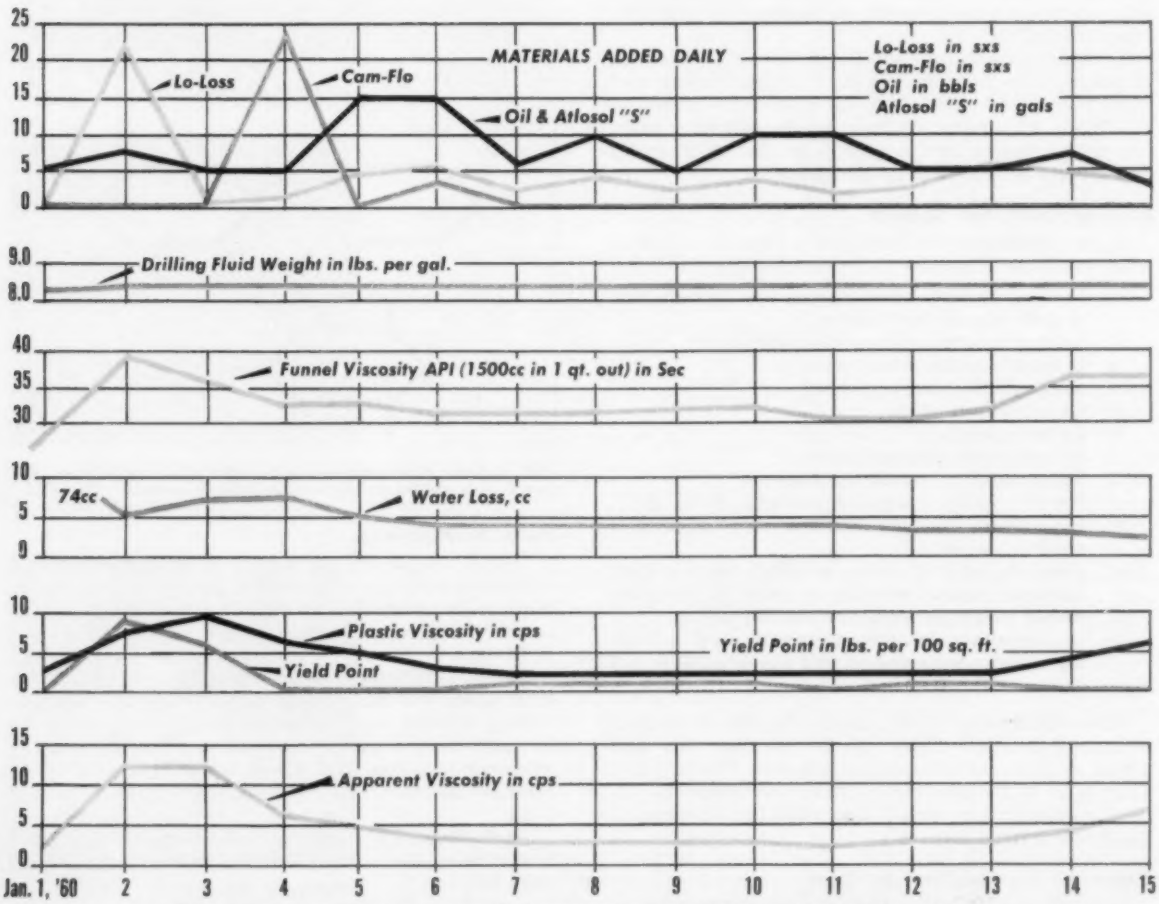


FIG. 2. Characteristics of a guar gum-fresh water mud used in drilling a well in Terry County, Texas.

Daily Drilling Fluid Properties—Salt Water

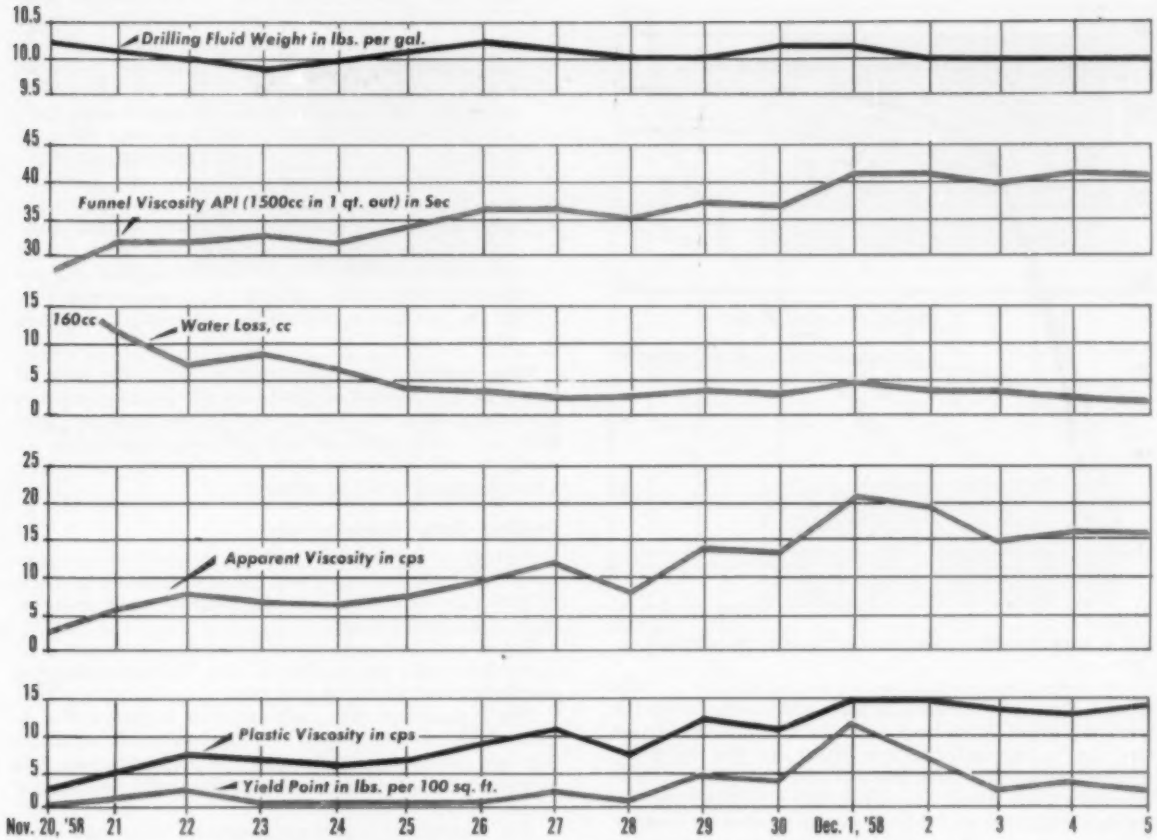


FIG. 3. Daily mud properties of a guar gum-salt water mud used in a Terry County, Texas, well.

County, (Fig. 3), the following materials were added:

500 lb gum
40 bbl oil
80 gal non-ionic emulsifier

Fluid properties before and after this addition were:

	Base Fluid	*Conditioned Fluid*
Mud weight — lb/gal	10	9.95
Funnel viscosity — sec/qt	28	35
Apparent viscosity — cp	2.5	11.25
Plastic viscosity — cp	2.5	8.5
Yield point — lb/100 sq ft	0	5.5
Initial gel — lb/100 sq ft	0	0
10 minute gel — lb/100 sq ft	0	0
Water loss — cc	No control	3.8
Filter cake — 1/32 in.	—	Film
Chloride ion — ppm	192,000	185,000
Ca and Mg as $CaCO_3$ — epm	35,000	35,000
Solids—% by volume	—	1.0
Oil—% by volume	0	6.5

Performance Characteristics

In the past two years, approximately 50 wells have been drilled in West Texas and eastern New Mexico employing various forms of guar gum as a viscosity and fluid-loss agent. Successful results were obtained on all but six of the wells observed.

From these wells and from lab studies it is evident that:

1. Guar gum attains a maximum swell and yield point in two to three hours as indicated by Fig. 4.

2. Guar gum shows excellent fluid loss reduction ability in the presence of a minimum amount of drilled solids.

3. Dispersion can be attained by additions of a minimum amount of organic or inorganic deflocculants.

4. It has been noted that the gum dispersions give an excellent inhibiting effect resulting in a minimum retention of drill solids.

5. Guar gum muds show a reduction of viscosity with increase in temperature, however, a minimum is attained at 180 F and it readily recovers when allowed to cool as illustrated in Fig. 5.

6. Guar gum shows no appreciable viscosity reduction from shear.

7. When used in brines or fresh water systems, bacteria or enzyme reaction has a deleterious effect on guar gum in its present form. It is recommended that a bactericide be used.

8. Guar gum is compatible with either cationic, anionic or non-ionic surfactants.

9. Cost of producing a barrel of mud using guar gum is comparable to starch-clay or NaCMC-bentonite compositions for the same viscosity and fluid loss characteristics.

10. Electrical logs run in this type of drilling fluid offer no problems in respect to interpretation.

11. Gum-surfactant emulsions have shown a marked reduction in drill string torque. In one crooked hole, the torque was varying from 200 to 400. After mudding up with the gum emulsion, the minimum torque reading was 100 and the maximum 115. Backlash, noted on connections prior to mudding up, was eliminated completely after mudding up.

12. Recent surveys indicate that gage holes can be drilled using this type of fluid. Caliper surveys have been run on

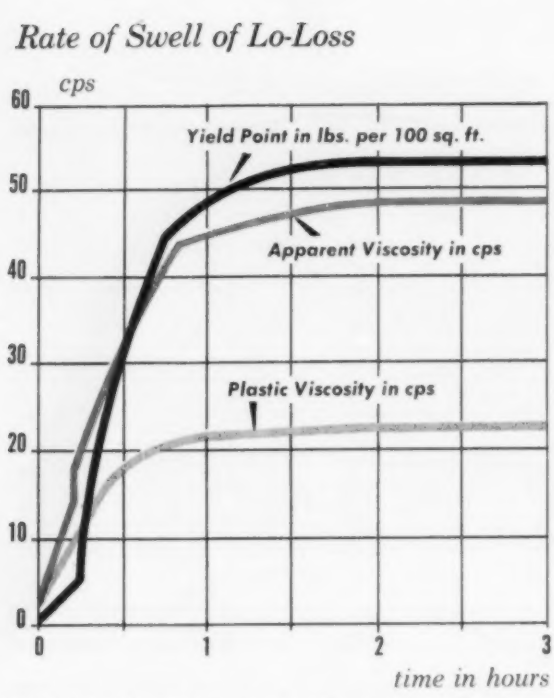


FIG. 4. Rate of swell of guar gum stabilizes after approximately two hours.

several of the wells using guar gum emulsions in both salt and fresh water. It has been indicated that a closer to gage hole can be expected, and it is hoped that this will prove to be universal. If it does, this will offer the opportunity to use much lower annular velocities than presently employed through long sections of shale in various parts of the country. This in turn will afford the opportunity to use higher jet velocities and horsepower at the bit, assuring attendant increases in rates of penetration.

13. Muds using guar gum for fluid loss control exhibit a marked reduction in invasion, resulting in more accurate core analysis. A report by the chief geologist for Great Western Drilling Company bears this out in a comparison of core analyses of two Prentice field wells, one using starch clay surfactant mud, the other gum-surfactant mud.

> "In November, 1957, Great Western Drilling Company No. 12-A Brit Clare was drilled in Section 22, Block D-14-CM&RR Survey, Terry County, Texas, using a starch surfactant mud. The Glorietta section was cored and microscopic inspection showed the regular Glorietta pay section to be completely water saturated to the extent that each core chip would actually drip water. Core analysis showed the zone to have fairly high oil saturations with water saturations low enough to indicate production. The average permeability was 5.8 millidarcies. Had this been a wildcat well, however, and had we not known that this zone was encountered above the oil/water contact for the field, no completion attempt would have been made. There would have been no reason to suspect that invasion and flushing had taken place due to the decreased bottom hole pressure in this reservoir. Since the zone was encountered above the oil/water contact, the well was cased and completed. It pumped 126.2 bbl of oil per day, plus 22.3 bbl of water per day through perforations. The water production decreased after a few days.
>
> "Approximately 13 months after completion of this well, No. 1-B Brit Clare was drilled in Section 27, Block D-14, CM&RR Survey, approximately 4300 ft southwest of No. 12-A Brit Clare. It was drilled with a low water loss gum-surfactant mud. The Glorietta pay zone was cored and the 12-ft granular zone had an average of 12.1 millidarcies of permeability, more than twice the permeability recorded in No. 12-A, yet it was not flushed by the drilling fluid and the core chips were completely oil saturated with no evidence of water. Core analysis revealed that even this zone was twice as permeable as the No. 12-A, it had higher oil saturations and consistently lower water saturation, and confirmed the previous assumption that the No. 12-A had undergone considerable invasion and flushing by a less desirable drilling fluid. This was very significant to the geologist as it enabled him to see and properly evaluate the pay zone, and to make qualified recommendations to the production department concerning completion of that zone."

Hole problems have been encountered in the form of fillups. In most cases, these have been alleviated by increases in viscosity. However, it is felt that if these problems could have been anticipated and attendant viscosities raised accordingly, the extremely high viscosities that have been found necessary could be reduced.

Drilling Rate Comparison

A group of drilling rate comparisons show various benefits for both the contractor and operator resulting from use of guar gum as a water loss and viscosity agent in either fresh or salt water fluids.

Fig. 6 and 7 compare performance of a salt water clay-starch fluid with a gum-surfactant fluid. The curves illustrate benefits derived by use of guar gum.

Fig. 8 compares (a) a low-solids oil emulsion, (b) an oil-in-water emulsion, and (c) a gum-surfactant emulsion. The low solids characteristics of the gum-surfactant fluid permitted use of tungsten-carbide bits which maintained above average penetration.

Fig. 9 compares a gum-surfactant-salt water fluid and a

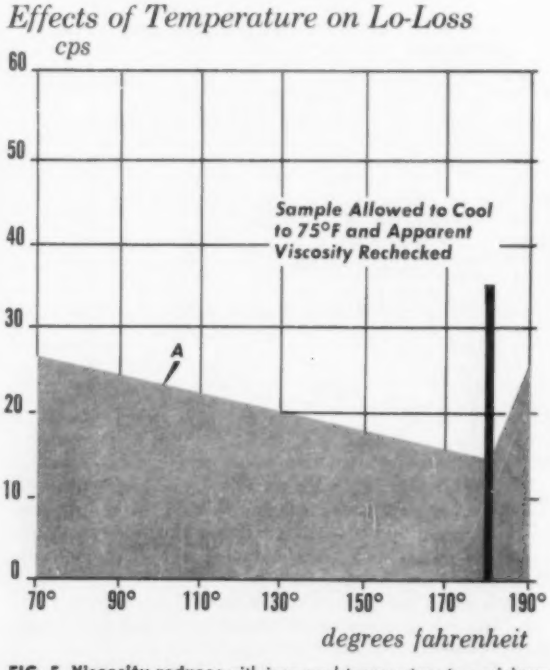


FIG. 5. Viscosity reduces with increased temperature to a minimum at around 180 F. However, viscosity recovers when fluid is cooled.

Clay-Starch, Gum Muds Comparison

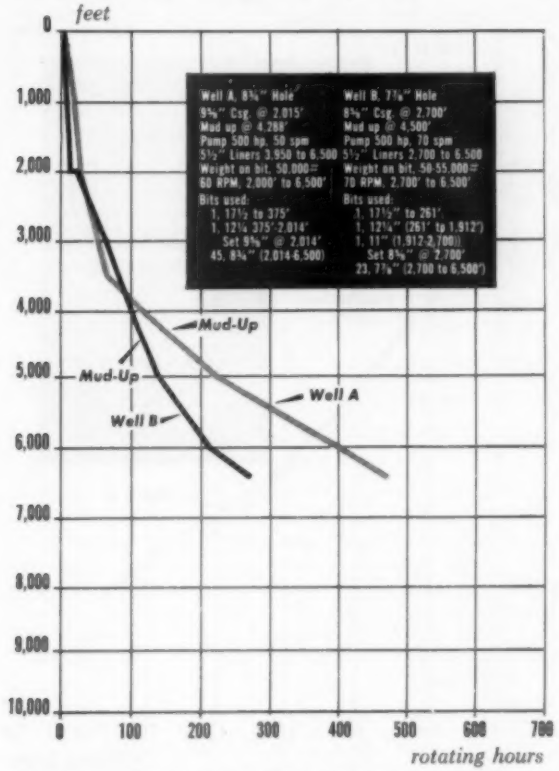


FIG. 6. Comparison of two wells, one drilled with clay-starch mud and the other with guar gum mud, illustrates benefits gained from the gum mud.

Salt Water Emulsions Comparison

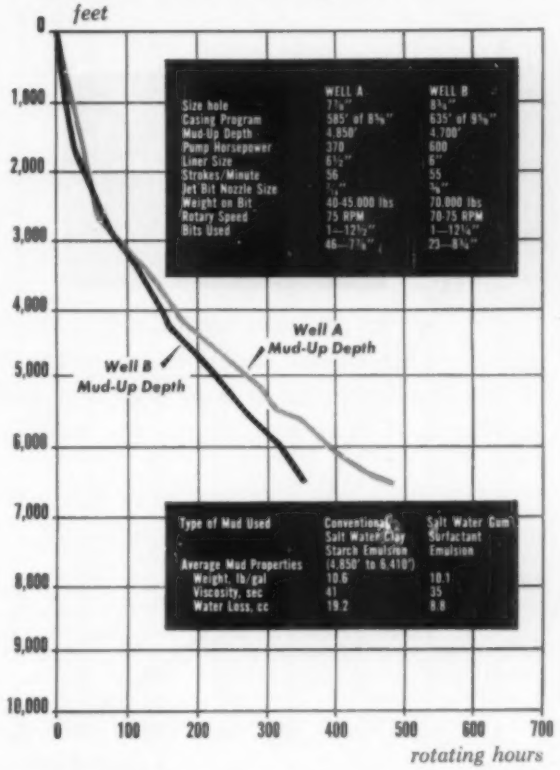


FIG. 7. Two wells drilled with salt water emulsions illustrate advantages of salt water-gum-surfactant emulsion over conventional salt water-clay-starch emulsion.

fresh water low-solids NaCMC fluid. Although mud costs were higher on the gum-surfactant well, savings in the cost of casing more than offset this added expense.

Preparation, Maintenance, and Testing

In using guar gum in drilling fluid formulations, it is felt that the order and method of adding the materials is very important. A reduction in material consumption may be noted if the following procedures are observed for the initial mud-up:

1. If possible, add 6 to 10 lb of flocculant over several circulations to clean circulating system of excess solids prior to mudding up, and clean all pits. If possible have solids reduced to 1 to 2 percent by volume.
2. Add 5 percent oil and 2 gal non-ionic emulsifier per bbl of oil prior to adding gum.
3. Add organic deflocculant to system to disperse and reduce yield point to a minimum.
4. Add desired amount of guar gum through barrels which are rigged up at pump suction. To one barrel add approximately 42 gal of oil, 2 gal non-ionic emulsifier, and 50 to 150 lb of gum. Stir with shovel and add through suction. Usually ½ to 1½ lb per bbl gum is sufficient on the initial mud-up, dependent upon desired viscosity (Fig. 11). Add total amount of gum over one or two circulations.
5. As gum is being added, add preservative to system (½ to 1 lb of preservative per bbl of mud).
6. After gum is added, adjust pH to 8 with lime.

Maintenance. Add daily treatment of guar gum for viscosity control through barrels at suction. To a barrel, add 42 gal oil, 1 gal of emulsifier, and desired amount of gum. Usually a daily treatment of 5 bbl oil, 5 gal non-ionic emulsifier, and 50 to 100 lb of gum will maintain a system.

For maximum benefits obtained from use of gum make all additions of oil and emulsifier through pump suction.

If the gum is added to a barrel containing approximately 42 to 50 gal of oil and 1 to 2 gal of non-ionic emulsifier, the gum will readily disperse in the oil. When the mixture is added to the system, the gum will hydrate efficiently. If added through the hopper, the gum has a tendency to ball-up and settle or float in the suction pit or it may go over the shale shaker screen at the flowline after circulation. Consequently, it is necessary to add the material slowly.

It has been found by field experience, that it is common for the shale shaker screen to fail to separate adequately the fluid and cuttings, resulting in a considerable loss of fluid to the shale pit. It is necessary to watch the screen carefully and keep it clean, or possibly by-pass the shaker. This can be readily done if a de-sander is used. The use of a larger mesh screen will sometimes solve this problem.

Lime should be added (daily, if necessary, to maintain pH) slowly through hopper or through chemical barrel in suction pit with maximum agitation from mud guns.

Deflocculant. Organic deflocculants may be added through the chemical barrel mixed with fresh water and 5 to 10 lb of lime or caustic soda. Usually on initial mud-up, it will take 1 lb per bbl dispersant for fresh-water systems or 2 lb per bbl for salt-water systems.

Hemlock bark extract should be used in salt-water fluids. Ferro-chrome-lignosulfonates may be used if the pH can be maintained economically at 8. It is imperative that an alkaline pH be maintained if ferro-chrome-lignosulfonates are used.

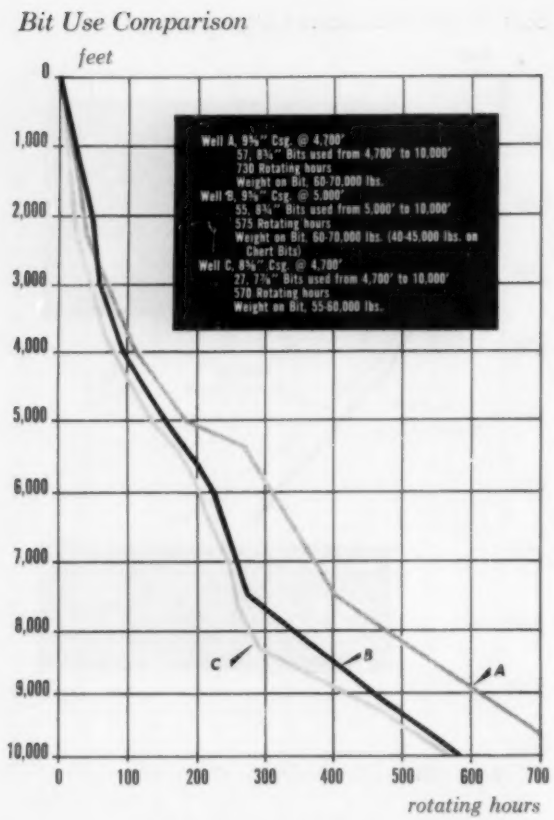

Bit Use Comparison
feet
Well A, 9⅞" Csg. @ 4,700'
57, 8¾" Bits used from 4,700' to 10,000'
730 Rotating hours
Weight on Bit, 60-70,000 lbs.
Well B, 9⅞" Csg. @ 5,000'
55, 8¾" Bits used from 5,000' to 10,000'
575 Rotating hours
Weight on Bit, 60-70,000 lbs. (40-45,000 lbs. on Chert Bits)
Well C, 8¾" Csg. @ 4,700'
27, 7⅞" Bits used from 4,700' to 10,000'
570 Rotating hours
Weight on Bit, 55-60,000 lbs.
C
B
A
rotating hours

FIG. 8. Comparison of drilling rate and bit consumption shows performance with (A) a low-solids oil emulsion, (B) an oil-in-water emulsion, and (C) a gum-surfactant emulsion.

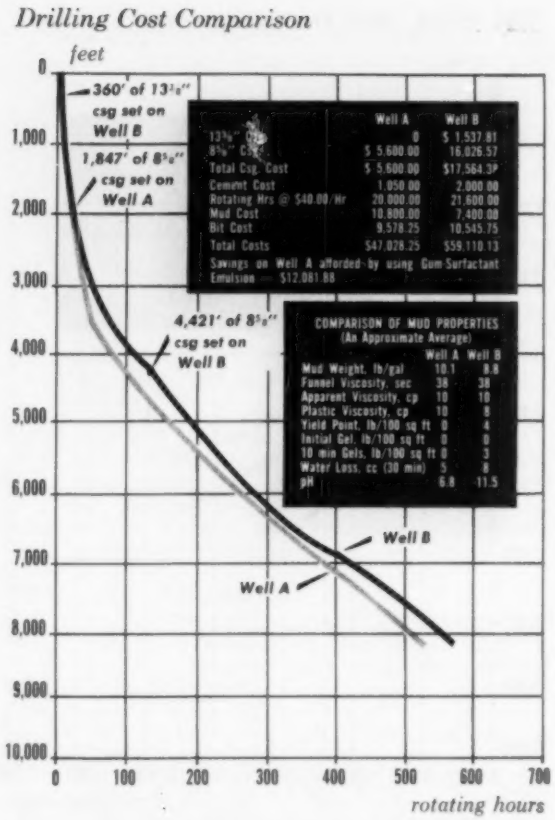

Drilling Cost Comparison
feet
360' of 13⅜" csg set on Well B
1,847' of 8⅝" csg set on Well A
4,421' of 8⅝" csg set on Well B
Well A Well B
13⅜" Csg. 0 $ 1,537.81
8⅝" Csg. $ 5,600.00 16,026.57
Total Csg. Cost $ 5,600.00 $17,564.38
Cement Cost 1,050.00 2,000.00
Rotating Hrs @ $40.00/Hr 20,000.00 21,600.00
Mud Cost 10,800.00 7,400.00
Bit Cost 9,578.25 10,545.75
Total Costs $47,028.25 $59,110.13
Savings on Well A afforded by using Gum-Surfactant Emulsion — $12,081.88
COMPARISON OF MUD PROPERTIES
(An Approximate Average)
Well A Well B
Mud Weight, lb/gal 10.1 8.8
Funnel Viscosity, sec 38 38
Apparent Viscosity, cp 10 10
Plastic Viscosity, cp 10 8
Yield Point, lb/100 sq ft 0 4
Initial Gel, lb/100 sq ft 0 0
10 min Gels, lb/100 sq ft 0 3
Water Loss, cc (30 min) 5 8
pH 6.8 11.5
Well B
Well A
rotating hours

FIG. 9. Cost comparison shows a savings in casing costs realized by using salt water-gum-surfactant drilling fluid as opposed to a fresh water low-solids NaCMC fluid.

In fresh-water fluids, other dispersants may be used if they are effective (determine by pilot testing).

A visual check should be made daily for possible flocculation. If flocculation occurs, add sufficient dispersant to deflocculate system.

pH control. The pH may be controlled with lime ($CA(OH)_2$), caustic soda (NaOH), or soda ash (Na_2CO_3). Lime should be used if at all possible. The pH should be controlled at 8. Do not let pH get above 8.5 or 9 because a higher pH will retard the hydration of the gum.

Preservative must be used in fresh or salt fluids (saturated salt water fluids included).

Conclusion

Guar gum has been modified to afford certain advantages in the preparation of a low solids drilling fluid. These benefits include better hydraulics and associated increase in rate of penetration, closer-to-gage hole that reduces expense of cement and mud treatment, and the possibility of reducing casing costs. Because the modified guar gum can be used in salt water, a drilling fluid is available that will have the minimum effect on clay materials in producing formations. Experience with the guar gum salt water emulsion fluid in a West Texas field has shown that it can be used to effect a normal completion in a zone formerly drilled with cable tools.

Acknowledgments

In acknowledgment, special thanks are due to J. A. Schlensker and J. N. Smith, Great Western Drilling Company; Sam Jones, Baroid Sales Division; and Sam Kohen, Emil Alter, and Jim Seaman, Stein-Hall, Inc. ★ ★ ★

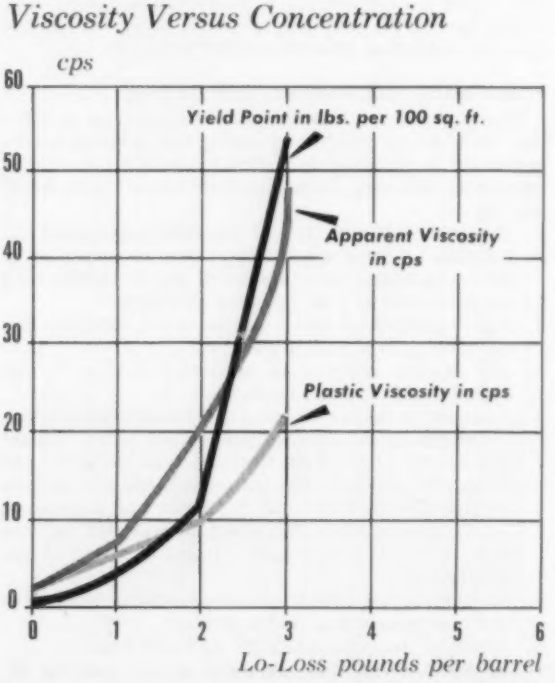

Viscosity Versus Concentration
cps
Yield Point in lbs. per 100 sq. ft.
Apparent Viscosity in cps
Plastic Viscosity in cps
Lo-Loss pounds per barrel

FIG. 11. Plastic viscosity, apparent viscosity, and yield point are illustrated as a function of guar gum concentration.

PART 7

New Developments in Nuclear Logging

New tools and a better understanding of radioactivity logging result in an improved analysis of reservoir rock and fluid properties

John C. Stick, Jr., *Lane-Wells Company, Houston, Texas*

RADIOACTIVITY LOGGING, which began its commercial career back in 1940, was the first method by which formation and formation fluid properties could be investigated through steel casing. This was a major "breakthrough" for the thousands of wells on which there were no logs or on which the available logs were inaccurate.

The first measurement was of the natural gamma rays emitted by the formation. These provided useful lithological data to distinguish the types of formations. This was soon followed by a measurement, called the neutron curve, in which the formation was bombarded by a source of fast neutrons.

The neutron curve was found to respond primarily to the hydrogen present in the formation. Accordingly, it became a very useful measurement for distinguishing porous from non-porous formations and, under favorable conditions, for actually measuring porosity. Following their introduction it has been found that nuclear radiation logs are equally useful in open holes. As a result, a number of new measurements have been developed which are important for well completion and formation evaluation.

Nuclear logs now range from very precise measurements made with highly specialized neutron generators to rather low quality gamma ray measurements made directly with casing perforating equipment to enable the perforations to be located precisely.

The object of this discussion is to describe briefly how radioactivity logs are made and to review the current status of this form of logging.

Radioactivity

In this nuclear age the terms alpha, beta, and gamma are almost household bywords. Even the once vague neutron is recognized as the heart of the atomic bomb and atomic energy. These are also the heart of nuclear radiation logging.

In its travel through matter, in logging principally formation and formation fluids, radiation undergoes many forms of interaction. In this short discussion it will be necessary to consider only the interactions which are the most important to the logging processes.

The alpha and beta particles really need not be considered in the logging process since their usefulness is confined to the generation of neutrons within the source and to the detection of both neutrons and gamma rays within the various types of detectors.

Gamma radiation. Gamma radiation plays an important part in the logging process. It can come from the spontaneous disintegration of natural earth materials such as uranium, thorium, and potassium. Or, it can be received as scattered radiation from a source of gamma rays carried on the subsurface tool.

Gamma rays are also generated by the stimulation of certain atoms by a process known as neutron capture. This capture process is most important to logging and will be discussed in more detail later.

Gamma rays from these various sources are evolved with a wide range of energies. Many elements have characteristic energy patterns known as spectra. They are absorbed and scattered by interaction with matter (in logging primarily with the heavier elements in the formation) before reaching the detector. Each interaction serves to reduce the energy of the gamma ray, a process called *degradation*. This degradation serves to change and to smooth-out any characteristic gamma ray spectra which elements may show, thus complicating their practical identification by spectral means under borehole conditions. This same process, however, does permit the use of gamma ray sources to measure the density of the media surrounding the tool, including the formation itself.

Neutrons. Neutrons are neutral particles which interact with matter in effect by bouncing around like balls until they are captured by the nucleus of some element. The capturing atom, raised to an excited state, may instantly emit ionizing radiation such as gamma rays. This has come to be called *prompt* radiation.

The atom may also emit additional radiation of the same nature during its "calming down" or decay period, which may last from a few milliseconds to many years. Such radiation is called *delayed*. The neutron capture process is different for each element and may be predominant for fast neutrons, intermediate energy neutrons (called epithermal neutrons) or very slow neutrons (called thermal neutrons because their energy is a function of the temperature of the region).

Since many elements found in oil-bearing formations have very characteristic neutron capture and decay patterns, these patterns can be used for identification purposes on nuclear radiation logs.

Hydrogen, and hydrogen alone, has the capability of rapidly slowing down neutrons. This is because its nucleus is about the same weight as the neutron. It, therefore, absorbs the maximum energy from the neutron in each collision.

In water, fast neutrons average about 18 collisions in less than 4 in. of travel before reaching thermal energy. It is this slowing down or "thermalizing" effect that hydrogen exercises on neutrons which is so important in measuring its quantity in the pores of the formations.

Generation and Detection Of Radioactivity

Radioactive sources. The most common neutron sources[1,17] which are utilized to bombard the formation produce about 5 million fast neutrons per second. They are made by encapsulating a mixture of radium and beryllium. The normally unwanted gamma rays from the radium are partially shielded out by use of lead and heavier metals. This is to improve certain types of neutron logs and so that the sources can be handled more safely in field operations.

Newer type sources utilize polonium, actinium, or plutonium mixed with beryllium to generate the neutrons. While these materials have the advantage of being essentially free of gamma rays, they also have one or more disadvantages such as short half-life, high cost, or poor availability. These disadvantages have served to restrict their use.

The identification of a number of important elements (such as oxygen and carbon) can be accomplished by neutron bombardment but require a source of neutrons having considerably higher energy than those produced by encapsulated sources. To generate such high-energy neutrons, new high-voltage neutron sources have been under development. One has recently been placed on field test and this source can produce ten or more times the number of neutrons, with each neutron having nearly three times the average energy, of encapsulated sources. Such strong sources of very energetic neutrons will not only permit new nuclear processes to be investigated but will produce "super accurate" conventional neutron curves. They are also very safe to handle in the field since they can be turned on and off at will.

Encapsulated sources of gamma rays are utilized for investigating the density of the media surrounding the borehole. These are commonly made either from metallic cobalt-60, an artificial isotope having relatively long life and strong gamma radiation, or from salts of radium.

Detectors of radioactivity. To detect radiation either an ionizing radiation which causes current flow in a gas or creates scintillations (light flashes) in a crystalline material must be utilized.[2] Ionization chambers and geiger counters are examples of detectors which utilize the former reaction. Recent subsurface instruments make use of a large scintillation crystal (normally of sodium or lithium iodide) combined with a very sensitive photo-multiplier tube which converts the tiny light scintillations into sizable electrical pulses. These pulses are further amplified for transmission to the surface over the conductor cable.

Scintillation detector systems are available to measure gamma radiation, and to convert thermal neutrons and the more energetic epithermal neutrons into light scintillations. The latter crystals permit a measurement of the thermal and epithermal neutron flux within the detector which is important to one form of neutron logging.

Unfortunately, high sensitivity photo-multiplier tubes are extremely sensitive to heat. This requires that the complete detector system be refrigerated for use in deep, hot wells and makes them unsuitable for the small sizes of instruments (1¾ and 1⅜ in. OD) required to go through tubing. For these small instruments geiger and proportional counters are commonly used.

The sources and detectors which have been described, when enclosed in high-pressure tubes, are the basis of all nuclear radiation logging processes.

Radioactive Logs

The gamma ray curve. For natural gamma ray measurements[3,4,6,18] any gamma sensitive detector can be used. In modern tools such a detector is commonly a 4-in. long scintillation crystal. This provides a much higher order of detail for thin beds than was possible with the older ionization chambers or geiger counters. The latter detectors had to be 30 or more inches long, with a corresponding reduction in response to thin beds, to attain comparable sensitivity.

An efficient detector, such as the scintillation type, is also highly advantageous because the level of gamma radiation from the formations is very low.

The neutron curve. Neutron logs[1,5,7,8,9,10] depend on both nuclear reactions and geometry to detect specific formation properties. Commonly, any encapsulated neutron source is attached below one or two detectors, at spacings ranging from 10 to 25 in. Fast neutrons, entering the formation, interact primarily with the hydrogen present in the fluid-filled pore space, and are eventually slowed down to thermal energy by these collisions. These thermal neutrons are readily captured by such elements as calcium, aluminum, silicon, etc. in the formation and detectable gamma radiation results.

The presence of a large amount of hydrogen in the surrounding formation, representing high porosity, reduces the number of thermal neutrons which reach the area near the detector, hence a minimum number of capture gamma rays are produced for detection. This results in a "low" reading on the curve.

Low formation porosity, which allows large numbers of neutrons to be thermalized in the area around the detector, results in "highs" on the neutron curve.

Such a measurement is called a neutron-gamma curve because a neutron source is used in combination with a gamma ray sensitive detector.

If a detector of either thermal or epithermal neutrons is substituted for the gamma ray detector, a very similar neutron curve is measured. This happens because the neutron flux actually within the detector itself goes hand in hand with that in the formation. Thus, in low porosity formations, where there are many thermalized neutrons available for capture by formation elements, there are also many thermal neutrons in the area of the detector. Accordingly, a large number are detected and recorded. The reverse is true for high formation porosities. This is called the neutron-neutron process because the detector is a neutron sensing device.

All types of neutron measurements are sensitive to the presence of gas in the region of investigation. Hydrocarbons in the gaseous phase are low in hydrogen concentration, and, accordingly, cause the curve to move in the direction of lower porosity.

While both the neutron-gamma and thermal neutron curves are sensitive to hydrogen, the epithermal neutron log detects hydrogen in the formation with less influence from borehole diameter changes and other extraneous effects. It is, therefore, particularly good for porosity measurements.

The arrangement of a typical modern simultaneous logging tool is shown in Fig. 1. The gamma ray portion is separated from the neutron source by at least 6 ft to remove it completely from the neutron field. Standard tools are around 3⅝ in. in diameter, twelve or more feet long, and will withstand 20,000 psi fluid pressure. They log at speeds from 20 to 50 ft per min.

Chlorine. It appears that chlorine has perhaps the most "affinity" of all elements normally found in formations for capturing thermal neutrons and emitting strong gamma rays. Since chlorine is most commonly associated with salt water, its detection provides a most useful log. Both neutron-gamma and neutron-neutron methods are nearly equally responsive to hydrogen. If the former is set electronically to emphasize the detection of the strong chlorine gamma rays, it will register significantly higher values as the amount of chlorine surrounding the instrument increases. Thus, by a comparison of the neutron and chlorine curves, the presence and even the amount of salt water in the formation can be evaluated.

Chlorine can also be detected by util-

izing its strong gamma ray production for spectral measurements. These are made by scanning the gamma ray energies with a spectrometer while the tool is standing still in the borehole. When chlorine is present, it will show up on the high energy portion of the spectral curve.

Oxygen. It was previously mentioned that the identification of oxygen and carbon in the surrounding formation can be important. This is because they provide a clue to the presence of oil. Water contains oxygen, oil does not. Therefore, other factors remaining constant, a reduction in oxygen would be expected as the amount of oil in the pore spaces increases. The reverse would hold true for carbon.

Oxygen is most readily detected by exciting it with a strong source of high energy neutrons and measuring the gamma ray decay products. Oxygen, so excited, emits strong gamma rays which decay over a relatively short period (7.3 sec half-life). Thus, if a powerful source of high energy neutrons is passed by the formation to irradiate it and, if at some known later time, a gamma ray detector is passed by, the gamma radiation the detector measures will be largely that from the oxygen in the surrounding media.

In practice this is accomplished by spacing the high-voltage neutron source about 6 ft from a gamma-sensitive scintillation detector and running out of the borehole at a predetermined, uniform speed.

Carbon. For carbon detection a short spacing from source to detector is commonly used and the circuitry arranged to emphasize the energetic, prompt gamma radiation from carbon. Measurements of this type are still in the preliminary stages of field experimentation.

Silicon. Another interesting measurement utilizes this same decay technique. This makes use of the longer 2.3 minute half-life gamma radiation from silicon. It can be conveniently detected, for example, by using the longer spaced (12 ft) gamma ray detector of the high-voltage neutron source instrument on the "in" run.

Fig. 2 shows the arrangement of the present high-voltage neutron source tool. A 6-ft spacing separates the high energy neutron source from the oxygen log detector on bottom. The gamma ray detector, also used for the silicon log on the "in" run, is some 12 ft above the source. With this instrument a gamma ray curve, conventional neutron curve, oxygen log, and silicon log are obtained on a single round trip into a borehole. Again the instrument diameter is 3⅝ in. and carries a 20,000 psi pressure rating. It is run at about 34 ft per min for the gamma ray, neutron and oxygen curves, and at about 6 ft per min for the silicon log.

The density log. The measurement of density by radioactive means[11,12,25] has been mentioned previously. It is accomplished generally in much the same manner as the neutron measurement only using a strong source of gamma rays in place of (or in combination with) the neutron source. Gamma rays penetrate the sides of the borehole and are scattered and absorbed in proportion to the average density of the surrounding media before reaching the gamma-ray detector. When the media density is low a proportionately larger amount of gamma radiation reaches the detector than when the density is high.

Measurement of approximate density can be made by electrically adjusting the standard neutron instrument to make it sensitive to the gamma rays

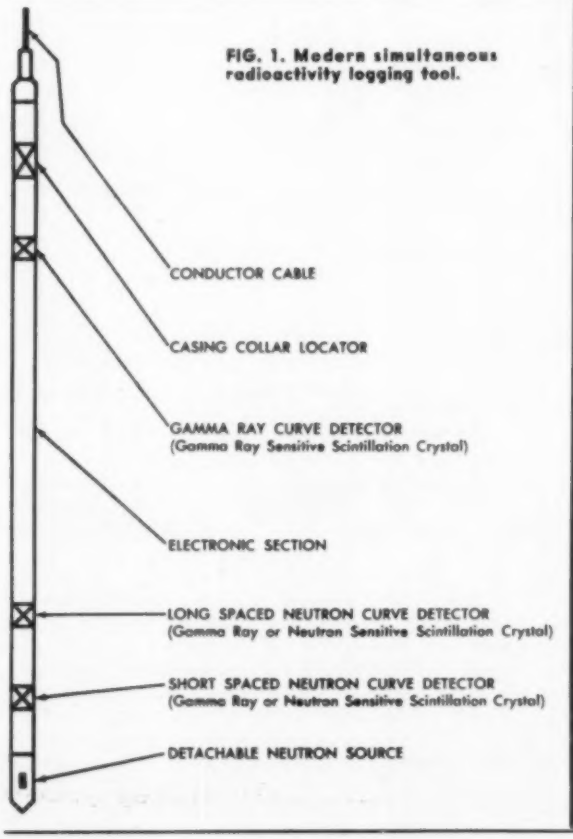

CONDUCTOR CABLE
CASING COLLAR LOCATOR
GAMMA RAY CURVE DETECTOR
(Gamma Ray Sensitive Scintillation Crystal)
ELECTRONIC SECTION
LONG SPACED NEUTRON CURVE DETECTOR
(Gamma Ray or Neutron Sensitive Scintillation Crystal)
SHORT SPACED NEUTRON CURVE DETECTOR
(Gamma Ray or Neutron Sensitive Scintillation Crystal)
DETACHABLE NEUTRON SOURCE

FIG. 1. Modern simultaneous radioactivity logging tool.

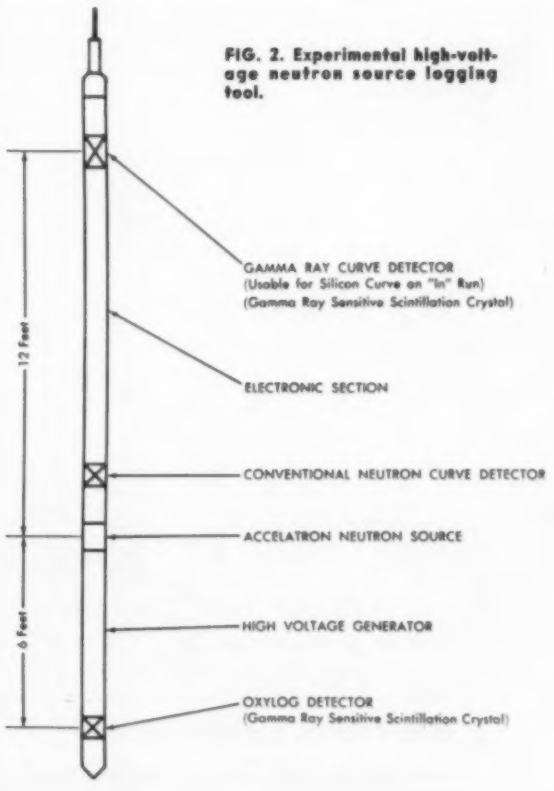


FIG. 2. Experimental high-voltage neutron source logging tool.

from a radium-beryllium source. This scheme is utilized in making logs for locating anomalies such as the top of the cement outside of the casing.

More precise density measurement requires a special tool. Such a tool is designed with a strong source of gamma rays and a suitable gamma ray detector along one side of the subsurface tool. The back side is heavily shielded against radiation.

This complete system is pressed against the side of an uncased borehole by a relatively strong spring. By this means the radiation is directed as much as possible into the formation. The scattered gamma rays reaching the detector provide a precise measurement of formation density. Fig. 3 shows the general design of a density measuring tool as it is operated against the formation face.

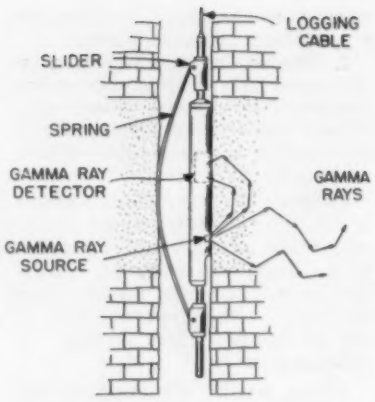


FIG. 3. Density logging instrument.

Uses of Radioactivity Logs

Nuclear logs have a wide range of capabilities for both cased and open hole measurements. This section will consider the more prominent uses which are made of them.

Location and identification of formations. Locating cased-off formations was the original objective of radioactivity logs and they have been invaluable for this purpose.[6,13,14] The contrast on gamma ray curves is provided by the radioactive elements usually contained in the shale, silt, etc. Thus, clean

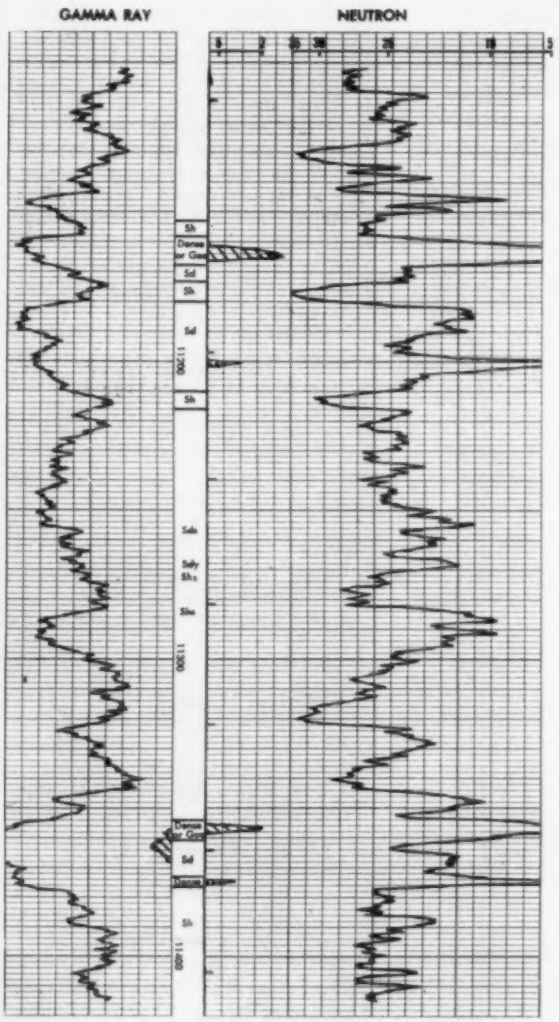


FIG. 4. Radioactivity log in sand area showing porosity evaluation.

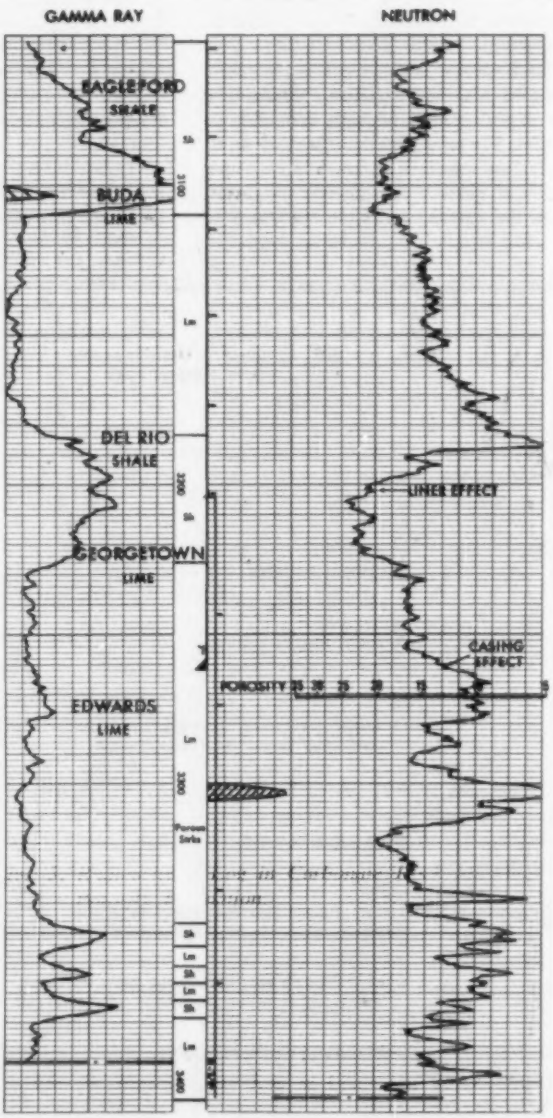


FIG. 5. Radioactivity log in carbonate rock showing porosity evaluation.

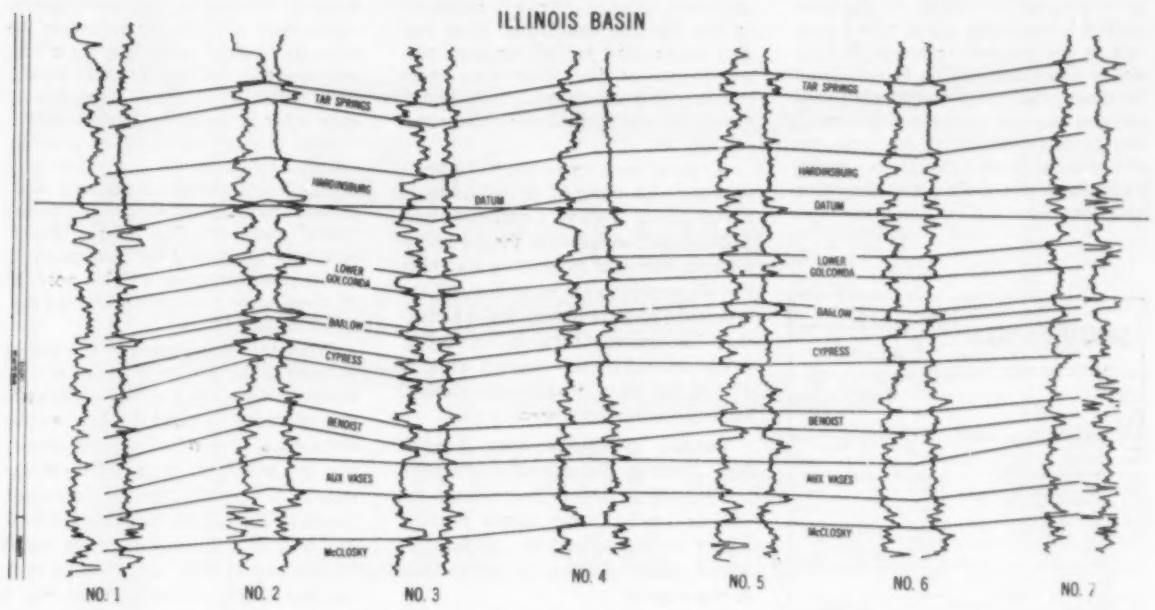


FIG. 6. Structural correlation in the Illinois Basin.

formations such as sand, limestone, dolomite, etc. record as lows (to the left) while shales record as highs (to the right). Shaliness in sands and carbonate rocks causes recorded values between these extremes, and it is important to recognize this in formation evaluation.

The detection and exact location of potential producing oil or gas horizons can usually be established even through several strings of casing. Fig. 4 shows a typical radioactivity log in a sandstone-shale sequence. The gamma ray curve (left) shows the lithology clearly. The neutron curve (right) indicates the tight non-productive or possibly gas-bearing areas within the porous zones.

Casing collars are shown as short pips along the center column for permanent depth references.

Fig. 5 is a similar section in carbonate rocks. The porous zones within the Edwards Lime are indicated along with a "tight" streak at 3300 ft and numerous shale stringers.

While gas sands can frequently be identified by their high response (due to lower hydrogen content) it is possible to confuse this with very low porosity (dense) formations. When borehole fluid invasion of the formation is present, but slight, this can be overcome by measuring neutron logs at two spacings (commonly called M.S. neutron curves). The short spaced curve will be influenced more by the invasion fluid, hence will show lower response (indicating the presence of more hydrogen) than the long spaced curve.

Special new logs such as the silicon log, although still in the experimental stage, should prove of interest in differentiating sands from carbonaceous rocks and in determining various lithologic mixtures of these materials. This can be important in identifying certain production horizons and in planning completion treatment for wells.

Structural correlation. The conventional radioactivity log (gamma ray and neutron curve combination) is excellent for indicating formation lithology.[14] Accordingly, in most areas it has proved extremely useful for structural correlation between wells, within fields and, where geological conditions permit, over great distances between fields. Frequently highly radioactive formations form prominent markers which can be used for identification over long distances. An example of correlation from the Illinois area is shown in Fig. 6.

Depth checks. The problem of knowing the exact depth of a producing horizon, particularly when zones are either very thin, or deep, or both, is ever present. Actual depths from the surface are not adequate for locating thin zones even with the best measuring systems. This problem can be solved by locating these zones through casing with the radioactivity log and tying them to casing collars with a simultaneous casing collar log, as shown in Fig. 4 and 5. The latter can then be used as "bench marks" to locate perforating guns exactly opposite the desired zone.

Recently, new gamma ray detectors which can stand the shock of perforating guns have been devised. These, along with their associated casing collar locators, are used as a service to provide exact depth control and even verification of the zone perforated. An example of such a log is shown in Fig. 7. The gamma ray curve clearly denotes the sand to be perforated and a rerun of the collar log shows precisely where the perforations were located. It should be noted that these charts are hand marked since they are always field copies.

Porosity evaluation using neutron curves. Reliable porosity values are among the most useful of all formation parameters.[15,16,19,20,22] In relatively clean sands or limestones any of the various types of neutron curves can be calibrated to read formation porosity directly.

The "cleanness" of the zone can be established from the gamma ray curve. Since the shales (including silt, volcanic ash, etc.) contain radioactive material they show as highs (to the right) on the gamma ray curve. The gamma ray curve is thus a good general means of measuring the "contamination" in sands, limestones, etc. Actual values of formation "shaliness" can be established for given well and formation conditions which will permit useful limits to be set for the quantitative use of the neutron curve.

Porosity scales for specific formation

and well conditions can be determined in a number of ways. A common method is to plot the actual core porosities vs the neutron response. Such a plot is illustrated in Fig. 8 and shows the close relationship commonly found between neutron response and formation porosity. Scales of this type can then usually be used directly on nearby wells which are drilled with the same hole size, etc.

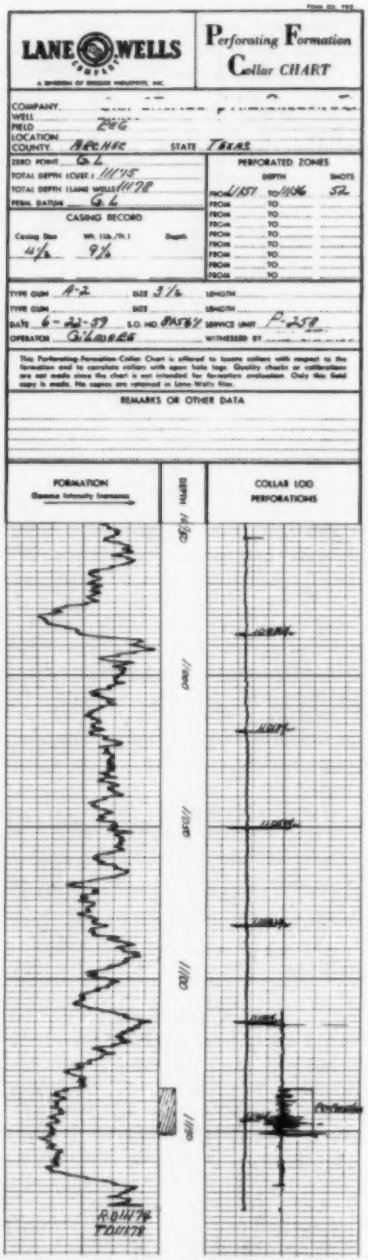


FIG. 7. Perforating-formation-collar chart showing location of perforations relative to producing zone.

When the physical borehole conditions vary, these charts can be corrected to suit the new conditions. Most logging companies publish neutron correction curves for their own tools which permit adjustment of the curves for a variety of well borehole sizes, salinity, etc.

A quick and reasonably accurate approach for porosity determination makes use of a 40 to 1 porosity scale. Such a scale, selected for the particular neutron curve, is located by matching the 40 percent point to shales and the 1 percent point to a very dense formation. The porosity scale shown on Fig. 4 was derived by this method while in Fig. 5 the porosity scale was derived from a neutron-core porosity plot.

Porosity evaluation using density logs. Since the density of a formation is inversely related to its porosity, the density log is a very useful porosity tool.[11] In fact, it has several features which make it particularly outstanding in this regard.

The neutron log is very responsive to porosity changes in the low porosity region and relatively insensitive in the high. By contrast the density log is very responsive in the high porosity region. Thus these two curves complement each other for porosity determinations.

Also, the neutron curve is severally affected by shale, silt and other contaminating materials containing nonmobile hydrogen which shows as "false" porosity. The density log is relatively unaffected by such material, hence produces more reliable porosity readings when such contaminating material is present.

When the grain density of the matrix is known, the density log can be calibrated precisely in porosity units without reference to cores or other empirical means. Generally the grain density can be estimated with sufficient accuracy when the type of formation (sand, limestone, etc.) is known. Charts and pocket scales are available which readily permit this calibration. A typical density log is illustrated in Fig. 9

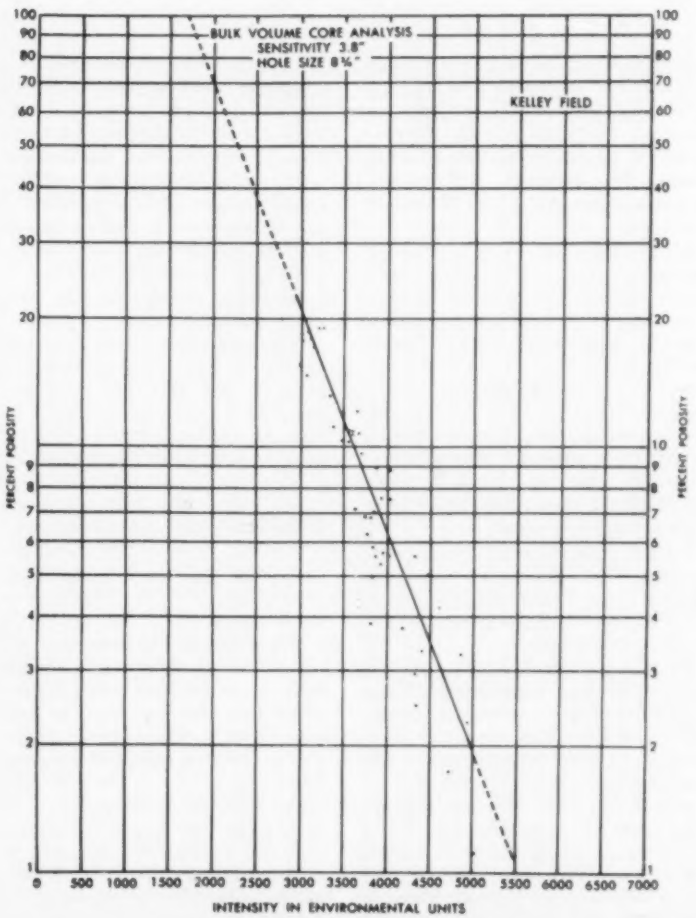
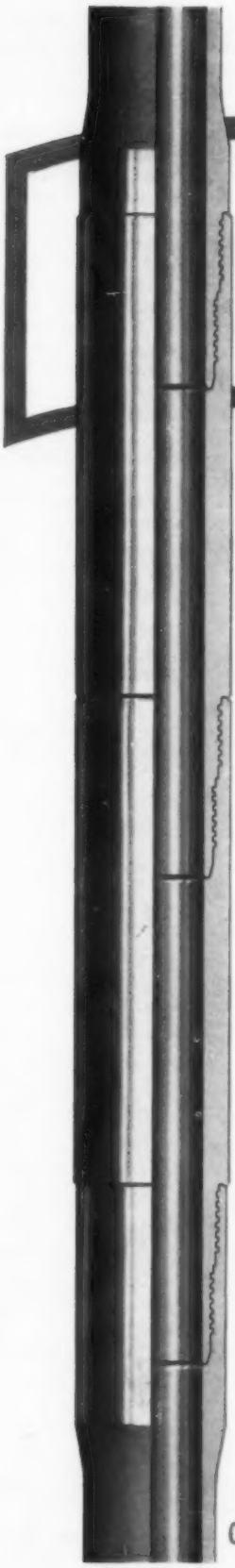

BULK VOLUME CORE ANALYSIS
SENSITIVITY 3.8"
HOLE SIZE 8¼"
KELLEY FIELD
PERCENT POROSITY
INTENSITY IN ENVIRONMENTAL UNITS
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000

FIG. 8. Neutron-core porosity chart.



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with a porosity scale derived from an estimated grain density of 2.72 gm per cc. The density-porosity relationship is very apparent.

It is important to have a borehole caliper log available when interpreting the density log due to its high susceptibility to large borehole diameter changes. Normally variations of an inch or so in diameter can be ignored but large washouts such as shown at 6330 ft make the logs unusable in such zones.

Formation fluid evaluation. Conventional gamma ray and neutron logs are normally not able to distinguish between oil and water in formations.[1,9] More recent nuclear radiation logs have such fluid differentiation as their objective and considerable progress has been made in this direction.

Since salt water is frequently associated with oil, logs which detect chlorine can be useful for determining water saturation. The "CL" curve normally registers salt water sands as deflections to the right of the "H" curve. (On a chlorine log the neutron curve is called the "H" curve and the chlorine sensitive curve the "CL" curve.)

If a completely saturated water sand is present, as is frequently the case, the response in this zone is used as a reference. Potential oil or gas bearing zones, having interstitial water about the same salinity, can be examined by use of a simple graphical plot using the "H" curve response as ordinate and the "CL" curve response as abscissa.

If the salinity of the water varies, a somewhat more complex relationship exists which also can be readily studied by use of graphical plots. In addition, nomographic solutions are utilized in particular areas for analyzing these "H" and "CL" curve relationships.

In favorable instances the contrast between the "H" and the "CL" curves is sufficient to permit the presence of salt water to be detected qualitatively by eye.

Since "CL" curves depend upon chlorine for their operation it is obvious that they become more quantitatively suitable as water salinity and formation porosity increase. The question of how low salinities and porosities can go and still permit reliable evaluation must be determined by experience.

An important consideration with chlorine logs is to assure either that the effect of mud filtrate invasion is negligible or that the invading fluid has been adequately dispersed from the region around the borehole. For this reason measurements with "CL" curves are most reliable when made in older wells in which formation fluid is almost assuredly right next to the casing. Under favorable conditions (very low filtrate invasion), successful logs have been made on newly drilled wells by waiting from three to thirty days after casing is set.

Fig. 10 shows a typical chlorine log on which zones containing salt water, oil and possible wet gas are indicated. In this instance the contrast is sufficient to permit reliable interpretation by eye.

As stated previously the oxygen log, while experimental at present, is ex-

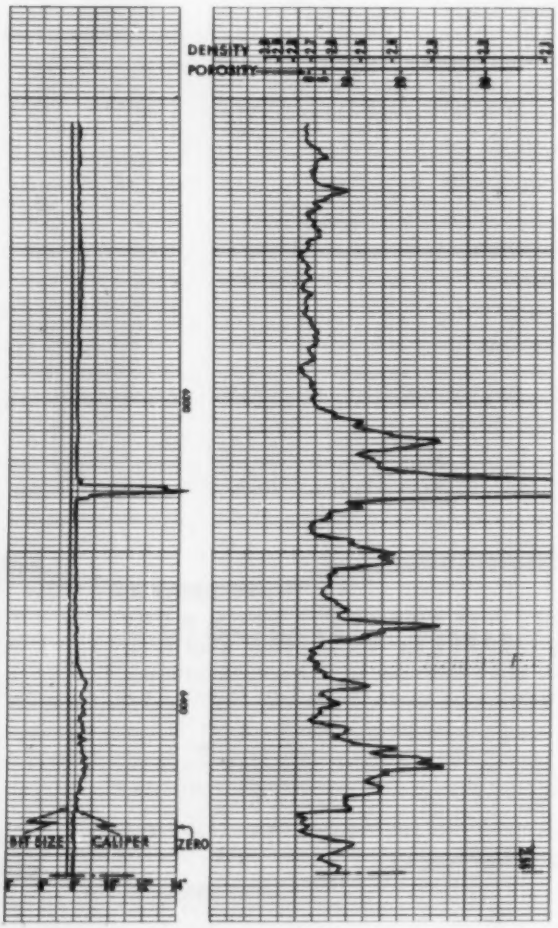

FIG. 9. Typical density log showing use of density-porosity relationship.

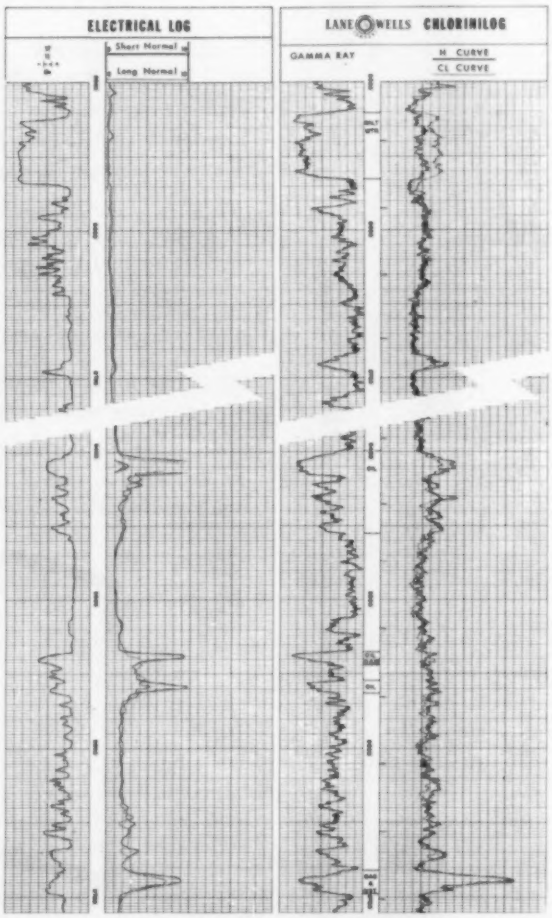

FIG. 10. Chlorine log-electrical log comparison showing response to oil and water sands.

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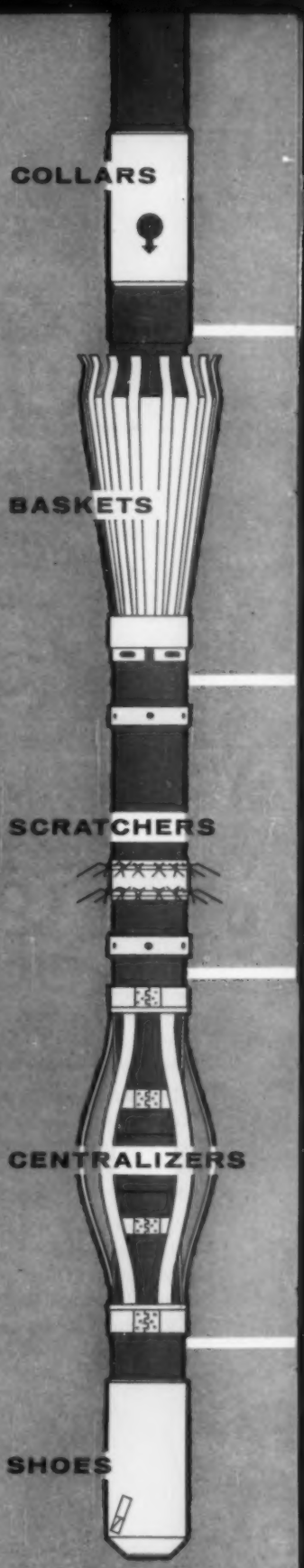
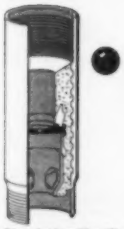


Differential
Fill-Up Collar
Product No. 1091 M&F

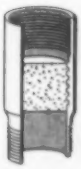
Flexiflow
Fill-Up Collar
Product No. 161 M&F



Circulating Flexiflow
Fill-Up Collar
Product No. 161-D M&F

Cement Float Collar
Product No. 101 M&F

Cement Baffle Collar,
with Hole
Product No. 104 M&F



Cement Baffle Collar,
Solid
Product No. 105 M&F

Triplex
Flapper Valve
Float Collar,
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Metal Petal Basket,
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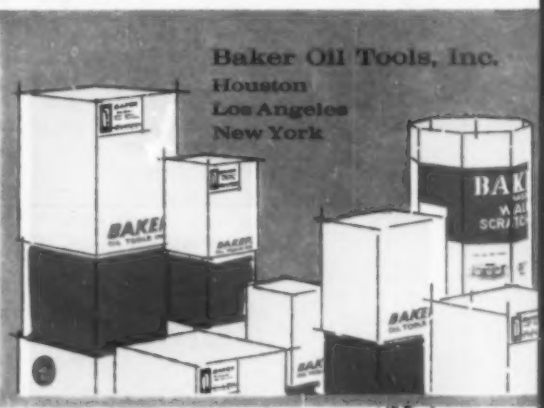
Product No. 343

Plain Hook-Up Nipple
with Metal
Petal Basket
Product No. 330

Avoid welding . . .
lock casing shoes
and collars with
BAKERLOK
Thread-Locking
Compound
Product 050



Hinge-Lok Wall
Scratcher, with
4½" long wires
Product No. 900-C

Hinge-Lok Wall
Scratcher, with
2½" long wires
Product No. 900-C

Solid-Ring Wall
Scratcher, with
4½" long wires
Product No. 901-C

Solid-Ring Wall
Scratcher, with
2½" long wires
Product No. 901-C

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Stop Rings
Product Nos.
940-B (Solid)
and 945-B (Hinged)

Rotating
Wall Scratcher
Product No. 903

"G-12" Slim Hole
Casing Centralizer
Product No. 910-G

"HN-15" Solid-Ring
Casing Centralizer
Product No. 908-HN

"HN-20" Solid-Ring
Casing Centralizer
Product No. 908-HN

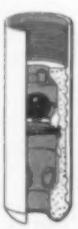
"H-15" Hinge-Lok
Casing Centralizer
Product No. 9115

"H-20" Hinge-Lok
Casing Centralizer
Product No. 9112

"H-25" Hinge-Lok
Casing Centralizer
Product No. 9113

Hinge-Lok Rigid
Casing Centralizer
Product No. 9133

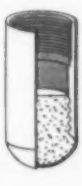
Differential
Fill-Up Shoe
Product No. 1081



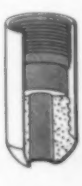
Flexiflow
Fill-Up Shoe
Product No. 160

Cement
Float Shoe
Product No. 100

Cement Wash-Down
Whirler Float Shoe
Product No. 120



Cement
Bull Plug Shoe
Product No. 103



Cement Guide Shoe
Product No. 102

Triplex Cementing Shoe Product No. 1363

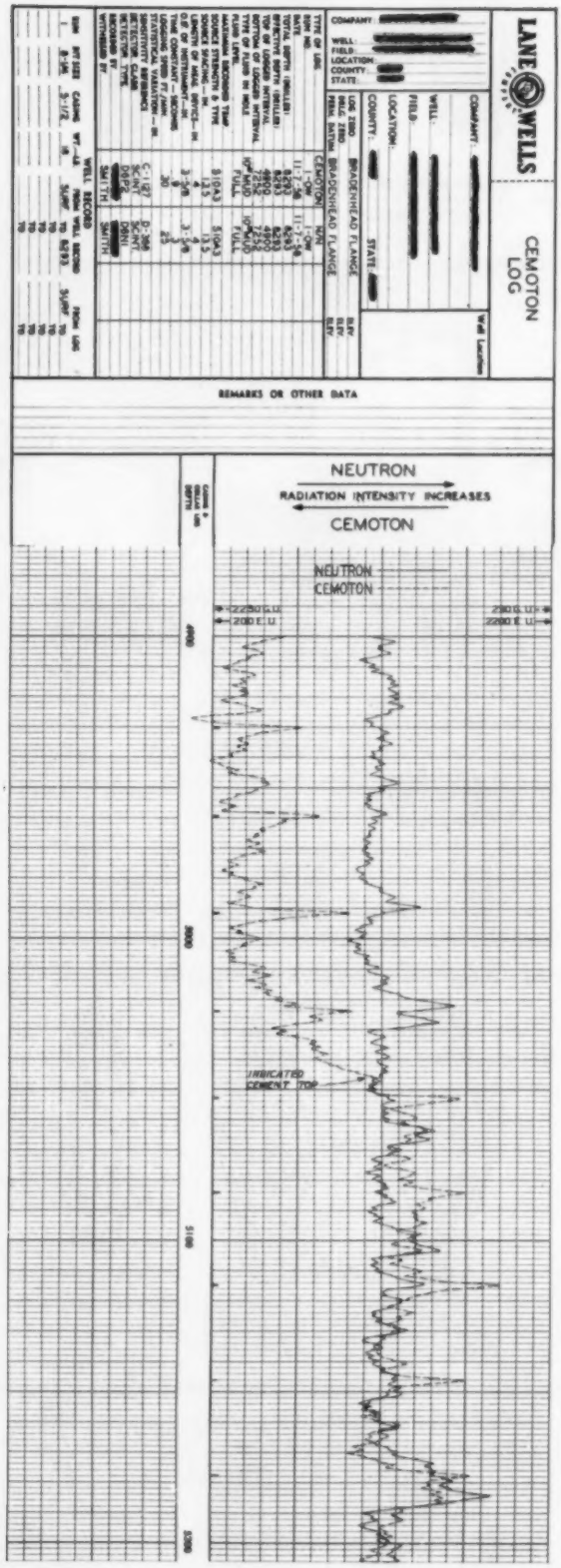


FIG. 11. Cement-locating log indicating location of top of cement.

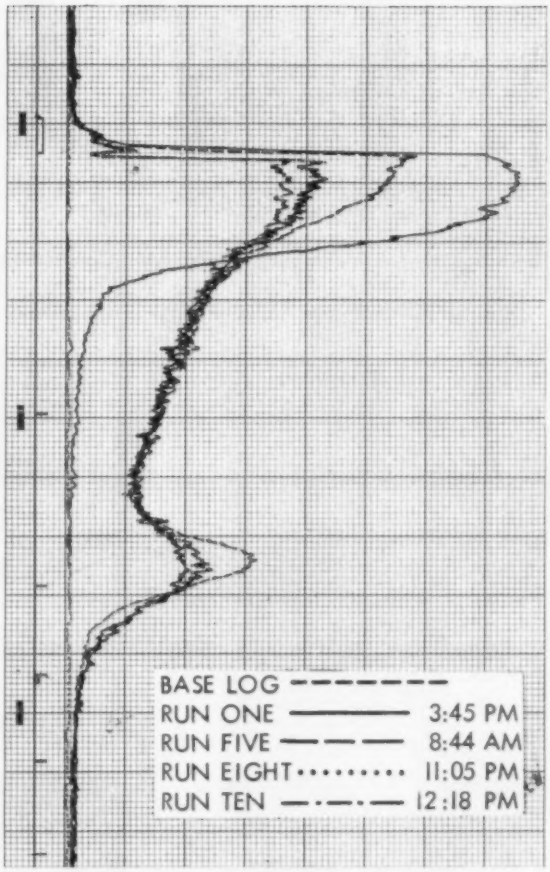


FIG. 12. Injection profile using particular radioactive tracer.

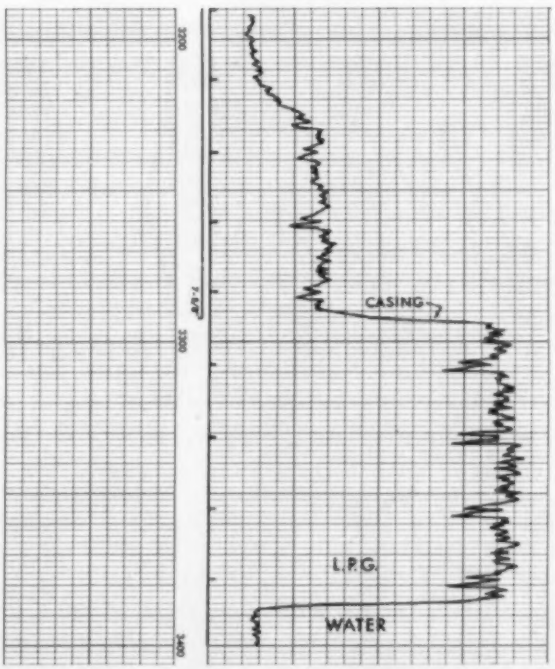


FIG. 13. Photon log of liquid petroleum gas storage reservoir.

pected to be an even better indicator of the presence of hydrocarbons than the chlorine log. This measurement has the advantage that it is independent of the degree of salinity of the formation water. Since water contains oxygen and oil does not, changes in the oxygen log within uniform formations should primarily reflect changes in water content. When porosity can also be determined, these variations in oxygen can reflect equivalent changes in hydrocarbon saturation.

The oxygen log is confronted with the same problem of mud invasion as the chlorine log. Mud filtrate tends to flush out the mobile oil within the lateral range of the investigation. Accordingly, the log is commonly run in casing, either on older wells or after time has elapsed to allow the mobile fluid to re-establish itself near the casing.

Location of cement tops. The location of the top of the cement outside of the casing is nearly always of importance to assure an adequate water shut-off. Radioisotopes, mixed in the cement slurry, have been used successfully for this purpose for years. The disadvantage of this method has been the inconvenience of having to obtain and mix the material during the cementing operation, and the fact that it disturbs the natural gamma ray log of the well. A relatively new curve which locates the top of the cement by measuring the change in density, is now available. This is accomplished very conveniently by a surface control on a conventional neutron instrument which makes it sensitive to the gamma rays from the radium-beryllium neutron source.

A typical log is shown in Fig. 11. The top of the cement is clearly indicated by a shift to the left. Severe channeling and loss of cement in cavities is frequently detectable.

Radioactive tracer applications. Numerous applications for radioactive tracers have developed during recent years and continual improvement in injection and measurement has furthered their usefulness.

Perhaps the most common use is to determine the zones of water entry in injection wells in waterflood projects. In solving this problem a suitable radioisotope tracer, chemically attached to fine particles of resin, is injected into the well from a special "injector" carried above a gamma ray instrument. Successive gamma surveys are made as well pressure is used to force fluid into the formation. The resin particles, being larger than the formation openings, result in the tracer being filtered off on the face of the formation in proportion to the flow of water into it.

An example of a water injection profile is shown in Fig. 12. The base radioactivity log is seen to be at such a low sensitivity that no formation response is evident. Run 1 shows the tracer slug entering the zone. In Run 5 the injection profile is taking shape. The similarity of Runs 8 and 10 show that the final profile has been reached. The amount of fluid entering each zone is represented by the intensity of the final curve opposite the zone.

Another common use for tracers is in locating the fractures in the various types of formation-tracing processes. Such methods commonly utilize sand grains as propping agents to hold the fractures open. Treating the last portion of the sand with a radioactive coating assures that the propping grains closest to the borehole will be activated. The location of the borehole entry of the fractures is then readily accomplished by a gamma ray survey.

LPG storage reservoir studies. The storage of liquid petroleum gas in large underground reservoirs is now very commonplace. In such reservoirs the LPG floats above the water which is used to fill the bottom of the reservoir and to extract the LPG as required. Due to irregularities in the cavern size, leaks, and general measurement inaccuracies, the exact amount of LPG requires checking at specified intervals.

This can be accomplished in a manner similar to the density log in which a gamma ray emitting source is used in combination with a gamma sensitive detector to measure a photon log. (This differs from a density log only in that it measures density all around the casing instead of concentrating on one side.) Run inside the tubing this device readily locates the LPG/water interface by detecting the gamma ray scattering due to difference in the density of the two fluids.

Fig. 13 is a good example of an LPG photon log. The density changes at the LPG, water and casing shoe interfaces are sharply defined.

Gas or water entry into producing wells. A new and interesting type of nuclear application has come to be known as a "flowing neutron" log. Its objective is to detect the entrance of gas or water into producing wells.

For gas entry a neutron source is utilized and the radioactivity logging instrument is used to survey the producing region while the well is actually on flow. Since gas contains very much less hydrogen than well fluids, the neutron instrument shows clearly points of gas entry into the borehole.

For water detection some success has been attained utilizing a photon density measurement. This is based upon water and oil having appreciably different densities.

Dynamic measurements of this type appear to be growing in interest since they offer the most direct means of improving gas/oil and oil/water ratios. Nuclear processes will be prominent in such "flowing" measurements since they most frequently must be made through tubing.

Conclusion

This discussion has been an attempt to describe the principles and types of radioactivity logs along with the uses which are made of them. It is hoped that this brief summary will be of assistance to those who are first being subjected to the art of well logging as well as those who use them so infrequently that they find it hard to keep up with the newer developments.

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★ ★ ★

PART 2.

Sample calculations using prepared charts simplify selection and sizing of small tubing and rods or hollow sucker tube pumping installations

WILLIAM D. SHANNON, *Dallas, Texas*

THE GENERAL DISCUSSION in Part 1* emphasized that there are a number of ways to lift fluids inside 2⅞-in. casing. In time, each of these methods will be evaluated by operators working with 2⅞-in. casing. The adaptability of each method, along with its maintenance, cost, and production records, when compared to other methods will establish the method to employ on later completions.

Conclusive field evaluation of all these methods will take considerable time. However, two of them lend themselves readily to 2⅞-in. casing and come quickly to the minds of operating personnel. They are the scaled-down conventional tubing and rods system, and the hollow sucker tube system. Of these two, the hollow tube is often the more favorable. Why? Because it stands to reason that the use of 2⅞-in. pipe as casing was born as a method to cut costs. Likewise, the artificial lift system employed should reflect the initial concept — reduced cost. In our operations, the use of hollow sucker tubes is either cheaper than, or competitive with, tubing and rods.

TUBING AND RODS

The use of small tubing and rods inside 2⅞-in. casing is a natural first choice for most operators. It incorporates several features found also in bigger installations of the same type. Some of them are:

A. Casing wear is minimized.

B. It can handle the allowable production in a majority of wells.

**Petroleum Engineer*, April 1960, Page B-27.

PUMPING INSTALLATIONS IN ULTRA-SLIM CASING

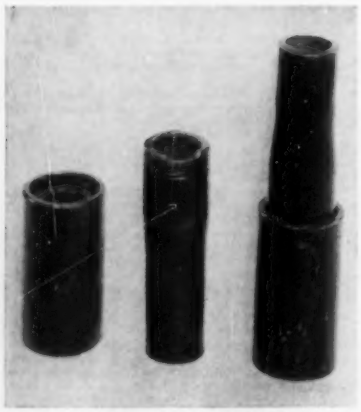
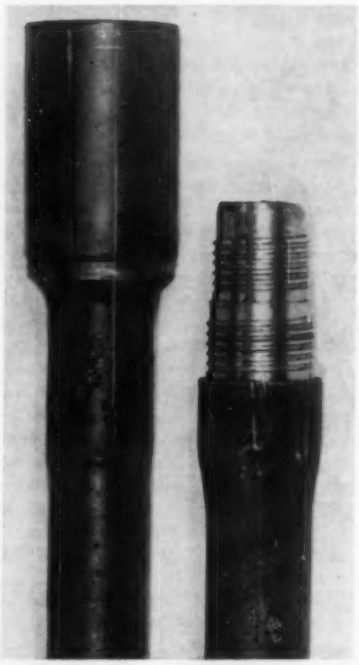
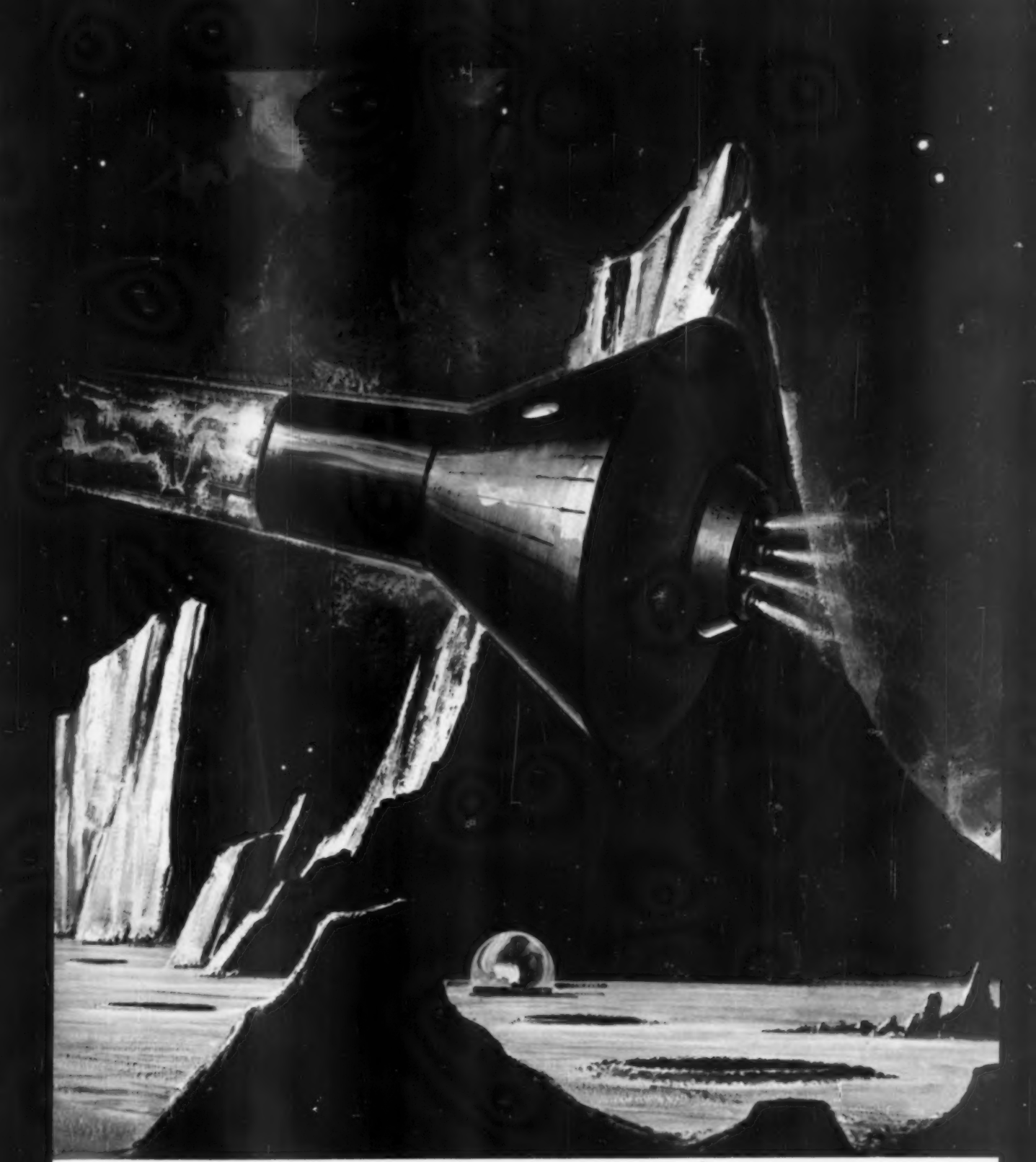


FIG. 1. Standard 1-in. EUE tubing used as hollow sucker tubes always failed at the last engaged thread when tested to destruction.

FIG. 3. Special joint designed for sucker tube tests features two lengths of threads with a landing between.

FIG. 2. Tool-joint type connection on hollow sucker tubes failed at the point of attachment in destruction tests.





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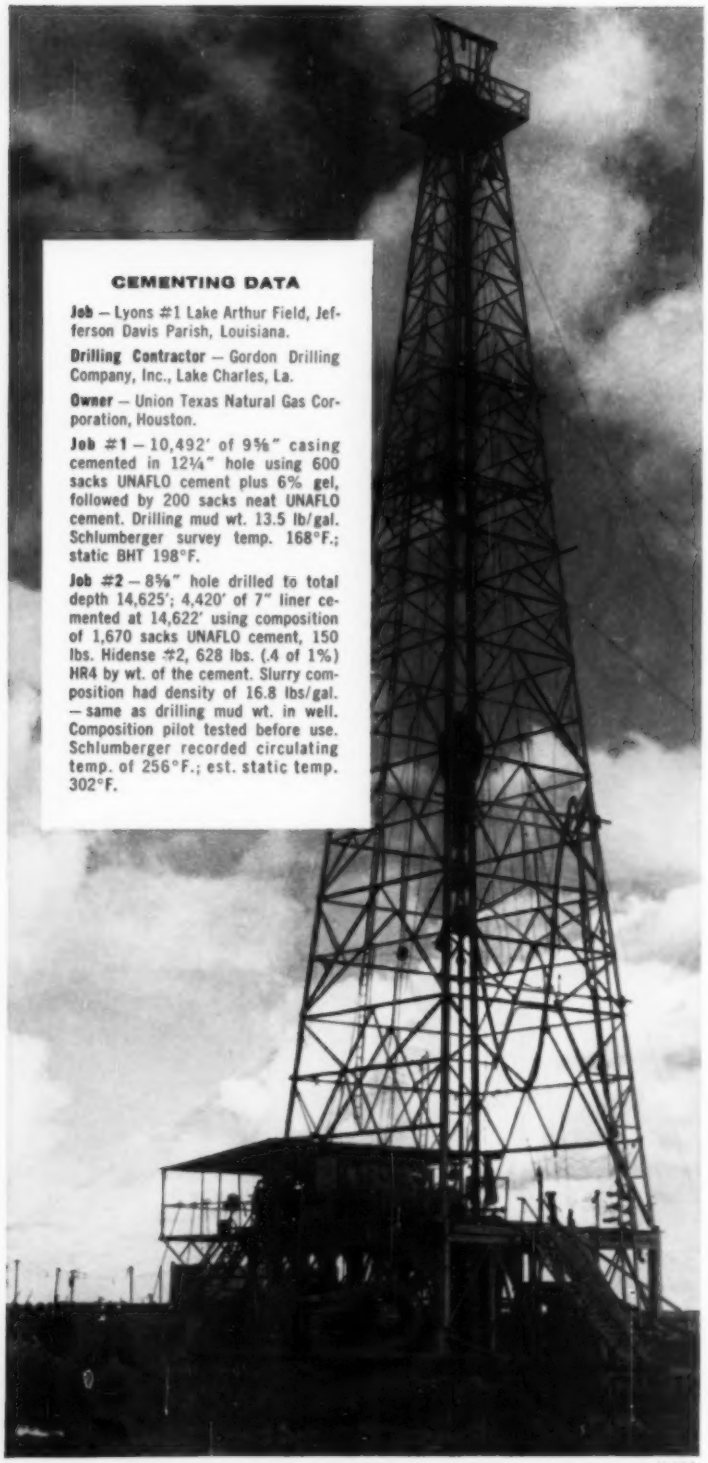

CEMENTING DATA

Job — Lyons #1 Lake Arthur Field, Jefferson Davis Parish, Louisiana.

Drilling Contractor — Gordon Drilling Company, Inc., Lake Charles, La.

Owner — Union Texas Natural Gas Corporation, Houston.

Job #1 — 10,492′ of 9⅝″ casing cemented in 12¼″ hole using 600 sacks UNAFLO cement plus 6% gel, followed by 200 sacks neat UNAFLO cement. Drilling mud wt. 13.5 lb/gal. Schlumberger survey temp. 168°F.; static BHT 198°F.

Job #2 — 8⅝″ hole drilled to total depth 14,625′; 4,420′ of 7″ liner cemented at 14,622′ using composition of 1,670 sacks UNAFLO cement, 150 lbs. Hidense #2, 628 lbs. (.4 of 1%) HR4 by wt. of the cement. Slurry composition had density of 16.8 lbs/gal. — same as drilling mud wt. in well. Composition pilot tested before use. Schlumberger recorded circulating temp. of 256°F.; est. static temp. 302°F.

U-164

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C. Its operating forces are easy to calculate and its equipment is easy to size because of experience in larger installations.

D. It is not new to field personnel.

E. The method uses extra steel in the combined forms of tubing and rods.

F. Pump repairs may require the removal of both rods and tubing.

G. Sand and paraffin are not easily controlled.

Production Limitations

The manufacturers of ½-in. sucker rods do not recommend installations at depths much greater than 5000 ft nor with volumes more than around 80 bbl per day. However, if certain limits are observed, greater volumes may be pumped using ½-in. rods. For example, assume that for both 1¼ and 1½-in. plungers, the maximum stress does not exceed 28,000 psi, the value of "C" does not exceed 0.25, and the lifted fluid is salt water weighing 404 lb per bbl. Since the area for stress is 0.196 sq in., the peak polished rod load (PPRL) will be (28,000)(0.196) = 5500 lb. Since "C" does not exceed 0.25, then the following expression should hold true:[1]

$$PPRL = W_f + W_r\left(1 + \frac{N^2L}{70{,}500}\right)$$

where

$$\left(1 + \frac{N^2L}{70{,}500}\right) \text{does not exceed } 1.25.$$

W_r for ½-in. rods is (0.73 lb/ft)(depth).

W_f = (plunger area − rod area) (pressure gradient), or, for this case, $W_f = (A_p - 0.196)(0.500)(\text{depth})$.

For a 1¼-in. plunger, $A_p = 1.228$ sq in. and by solving the expression for D_{max} the depth is computed as 3850 ft. For a 1½-in. plunger, the expression yields a maximum depth of 3220 ft. By a trial and error solution (with straight edge) of Fig. 9 using "C" = 0.25 as one limit, a group of stroke-speed combinations can be obtained which will satisfy the assumed conditions. If a 74-in. stroke limit is chosen, calculations of these stroke-speed curves will show that a

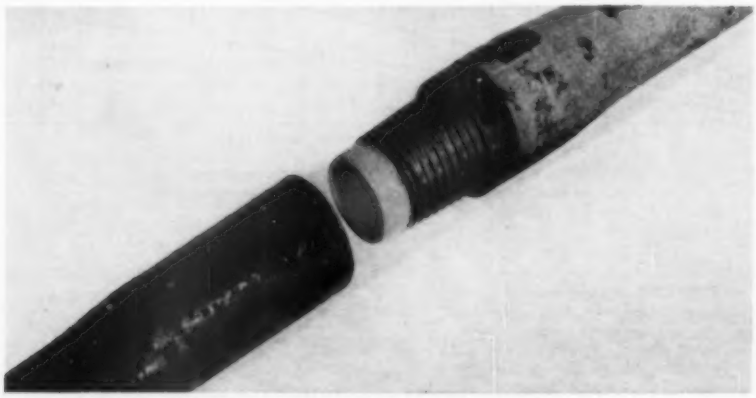


FIG. 4. Another special joint being tested uses a plastic seal at the inside landing.

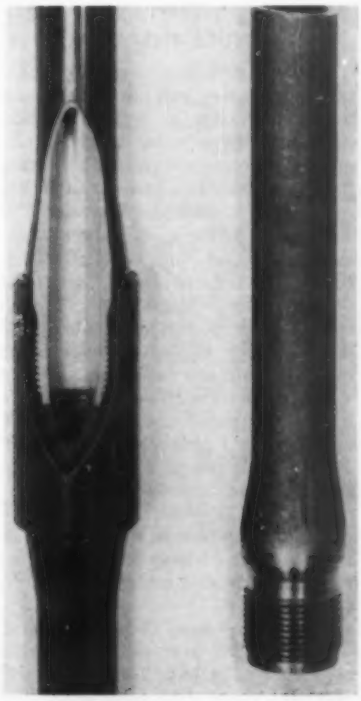


FIG. 5. Pin and coupling joint is being tested in North Dakota at a depth of 6200 ft.

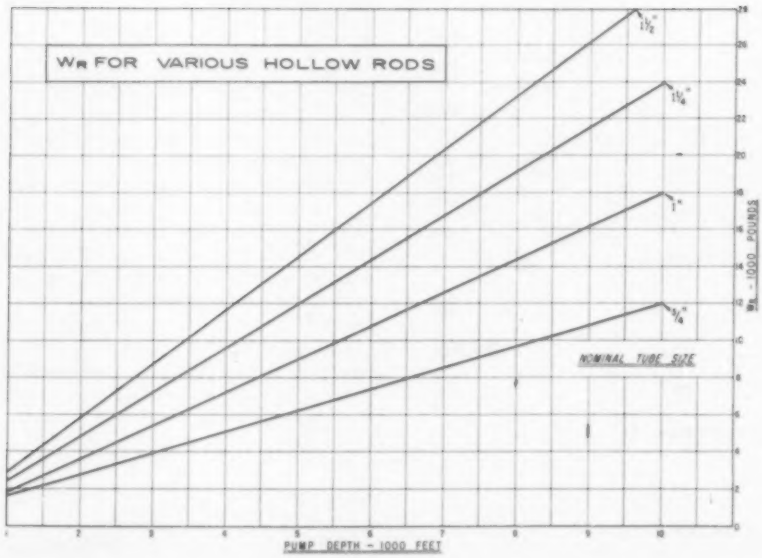


FIG. 6. Weight of various hollow rods (W_r) at pump depth can be determined from this chart.

74-in. stroke pulling 15 strokes per min could produce roughly 300 bbl per day with the 1½-in. plunger working at 100 percent efficiency. Of course, such an installation will not produce that much fluid but the point is that small tubing and ½-in. rod installations are computed and sized just as are bigger installations.

Repair and maintenance data for small tubing and rod installations are generally lacking. However, since sucker-tube pumping is still under development and the tubing-rods method is better known, the small tubing and rods will probably reflect a somewhat better maintenance history. This does not mean, of course, that the tubing and rods method is universally the better performer. Only a close look and comparison between groups of similar test wells can answer that question.

Any fishing job required in a small tubing and rods installation would be more complicated and difficult than a comparable job in a sucker-tube installation. Fig. 13 presents a graphic comparison of areas and clearances in the two types of installations.

SUCKER TUBE INSTALLATIONS

The use of hollow rods, or sucker tubes, is not new and has worked very well, particularly in shallow applications. Recently, as pump depths, speeds, and fluid volumes have increased, we have experienced an increase in hollow rod failures in some problem wells. The rods used in these wells were 1-in. EUE, J-55 and N-80 tubing (Fig. 1, right). The failures always occurred at the last engaged thread (Fig. 1, left and center). The geometry of the joint and the incidence of failures pointed to fatigue failure due to bending.

To combat the failures, we tested a tool-joint type connection (Fig. 2) which showed conclusively that when the threaded pin was made up on a shoulder, it outlasted the threaded and coupled rod. However, the failure location then moved to the point of attachment. This led us to a shouldered joint which was an integral part of the tube body.

Fig. 3 and 4 show three joint configurations which have been tested with excellent results. In wells pumping from 3000 ft, two of these have established uninterrupted pumping records of more than 8 months in wells which previously had pumped without failure no longer than 6 to 8 weeks with new strings of 1-in. EUE tubing.

Encouraged by these results, we have worked with various manufacturers to perfect a hollow rod or sucker tube joint which will reflect a cost advantage over the more costly off-shelf configurations. Several have been designed and two are now running at depths up to 6200 ft. Fig. 3 (left) shows one of these which, on April 1, passed more than 5,000,000 stress cycles at continuous speeds of 18 strokes per min or more. Fig. 5 (bottom assembled and cutaway; top, actual pin) shows another joint recently put under test at 6200 ft in North Dakota.

Our best production through sucker tubes has been 253 bbl of fluid per day from 3000 ft. Deepest application has

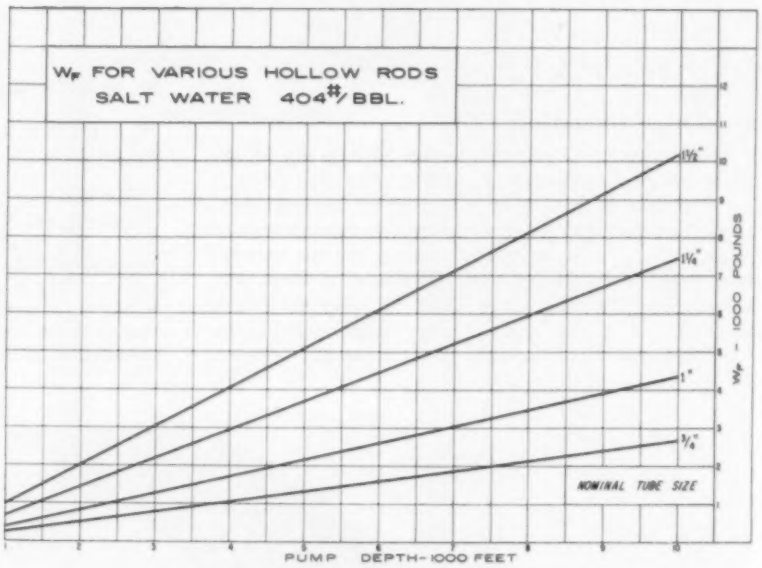
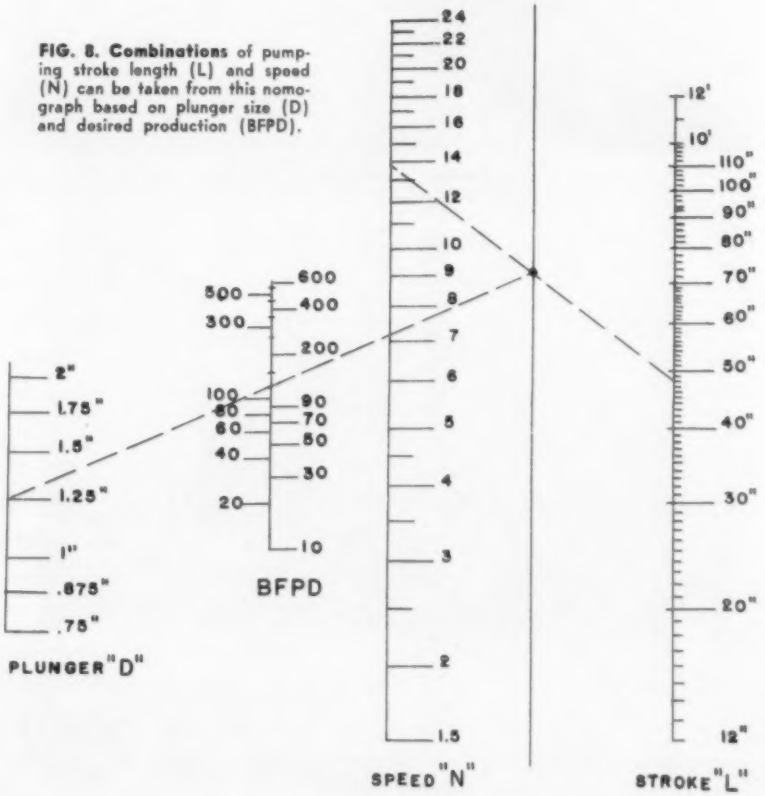


FIG. 7. Weight of fluid (salt water) contained in various hollow rods (W_f) is determined at pump depth.

FIG. 8. Combinations of pumping stroke length (L) and speed (N) can be taken from this nomograph based on plunger size (D) and desired production (BFPD).



been at 7300 ft. Both of these installations, along with approximately 250 others, have shown us that this method of artificial lift is successful. There are definite limitations and problems, but there are also some distinct advantages to the method.

General Limitations

Most of the limitations of sucker-tube pumping which can be stated at this time are of an empirical nature. They take the form of rules of thumb rather than equation. Some of them are: (1) Do not exceed 1½-in. in plunger diameter when using a 1-in. sucker tube regardless of depth; (2) To gain production, lengthen pump stroke rather than increasing speed; (3) Avoid the use of any tube smaller than 1-in. nominal; (4) Design and size the installation for continuous withdrawal of fluid rather than intermittent pumping; (5) Use a traveling barrel pump whenever possible; (6) Provide plenty of fluid and gas passage through and/or around the pump anchor; (7) Encourage good torque make-up of each joint and avoid scarring the hollow tubes. Absolute depth, speed, and volume limits of sucker tube or hollow rod pumping are yet to be established.

Sand and Paraffin Control

The hollow rod pumping method offers excellent control of sand and paraffin. Sand or gyp can usually be kept moving at sufficient speed to prevent deposit in the sucker tube. If these particles do settle back when the unit is stopped, the sand does not settle around the tube but rather is contained in the tube. If it can not be pumped free, the hollow rods come out easily for sand removal.

In most cases, paraffin deposition in hollow rods can be controlled by lining the hollow rods with a plastic which resists the adhesion of paraffin.

Sucker Tube Calculations

Until we started designing new sucker tube joints, little dynamometer card work had been done on hollow rod installations. As this work progressed, information from well pulling reports coupled with scattered dynamometer card data revealed definite failure patterns. It became necessary to compute peak and minimum loads not only from dynamometer cards but from basic known well conditions. The calculation of PPRL and MPRL for hollow rod installations differs considerably from calculation for tubing and rod installations.

Several authors[2,3] have worked on the problem of adapting the conventional load equations of rod type pumping to hollow tube pumping. The results vary somewhat, but since the problem is of an empirical nature, these results are a good start.

Peak polished rod load. The best approximation of PPRL that we have developed is:

$$PPRL = (W_f + W_r)(1 + C) + F$$

where W_f is total weight of fluid within the sucker tube,
W_r is total weight of the sucker tube in air, and
F is total friction force.

Note that the peak load is in no way affected by plunger size.

Minimum polished rod load. Several factors influence MPRL. Among them are: (1) hydraulic gradient of the produced fluid at the plunger face; (2) friction pressure of fluid moving in the hollow tube; (3) the net area difference between plunger diameter and sucker tube inside diameter, and; (4) the friction force between the sucker tube and the casing wall. One author[4] has investigated the forces due to

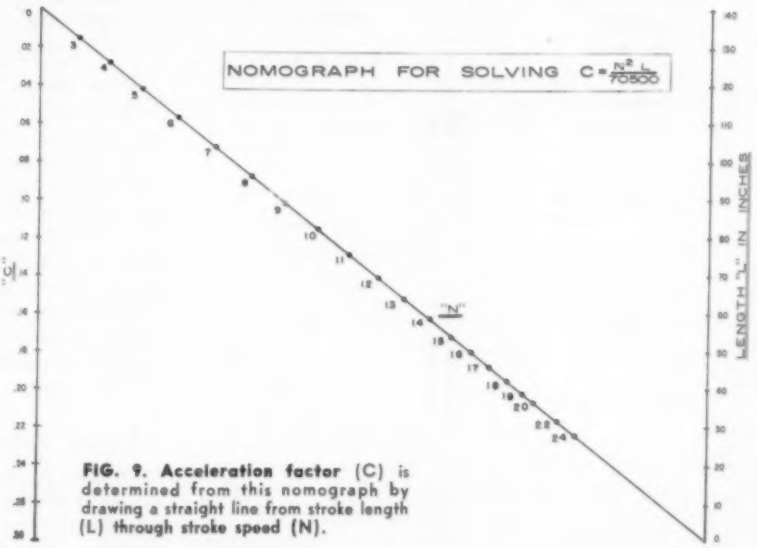


FIG. 9. Acceleration factor (C) is determined from this nomograph by drawing a straight line from stroke length (L) through stroke speed (N).

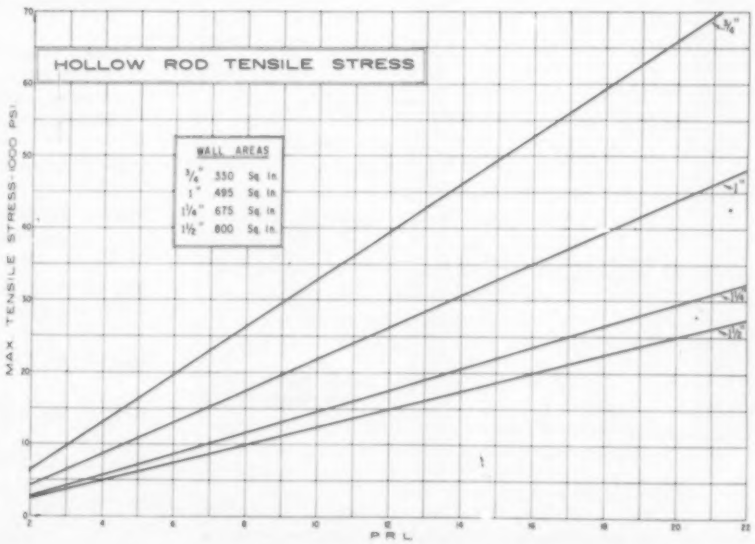


FIG. 10. Maximum tensile stress in hollow rods is dependent upon peak polished rod load (PRL).

the area difference between plunger and tube diameters. The magnitude of these forces is a function of the hydraulic pressure gradient within the sucker tube and the net difference in area between plunger and tube inside diameter.

An expression for the minimum polished rod load has been written[2] which takes into account all of the mentioned forces. It is:

$$MPRL = W_r(1-C) - [(A_p - A_r)\,(psi/ft)\,(depth)\,(1+C)] - F$$

Load due to rods. The term $W_r(1-C)$ is the weight of rods after they are accelerated downward and after the traveling valve has opened. When this valve is open, the fluid load is on the pump's standing valve and contributes no net load on the sucker tube.

Hydraulic unbalance. The term $(A_p - A_r)\,(psi/ft)\,(depth)\,(1+C)$ is the net hydraulic unbalanced force acting upward and which must be accelerated downward. It consists of the product of the area difference of the plunger and tube $(A_p - A_r)$ and the pressure on that area (psi/ft) (depth) which, since it must be accelerated, requires the factor $(1+C)$.

Fluid and casing friction. The final term (F) is the combined fluid friction within the sucker tubes and the casing wall. The fluid component is made up of pressure drop per 1000 ft (ΔP) times depth in 1000 ft (D) times the area of the inside of the tubes. This frictional force acts to lighten the apparent weight of the sucker tubes. The casing wall friction is an abstract value and is almost impossible to determine. In examining dynamometer cards, it is most practical to lump both the fluid friction and casing friction with the hydraulic unbalance term.

Other factors. Several factors enter the picture which tend to disturb the accuracy of the load calculations. They are hole crookedness, oil viscosity, working fluid level, and water and/or gas content. All of these contribute to change the values of hydraulic unbalance, fluid friction, and casing wall friction. The most reliable method of determining actual operating loads is to analyze dynamometer cards taken while an installation is on stabilized production. Examination of PPRL, MPRL, W_r, and $W_f + W_r$ from the cards coupled with strictly computed loads will indicate the magnitude of error due to total friction. This value makes it possible to predict more accurately the anticipated loads on future installations.

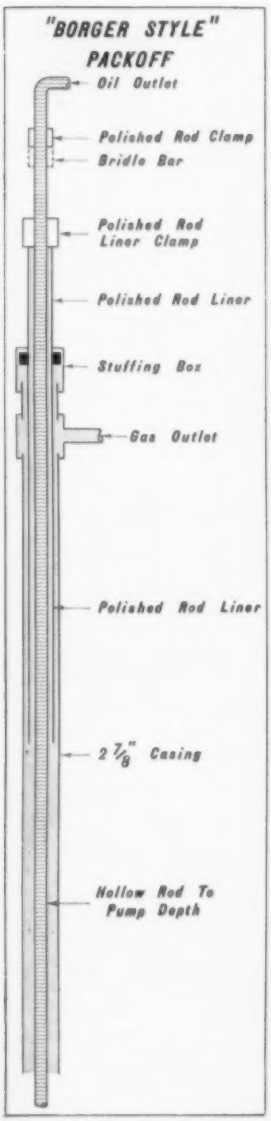


FIG. 11. "Borger style" packoff arrangement provides a continuous flow path for fluids coming up the hollow rod.

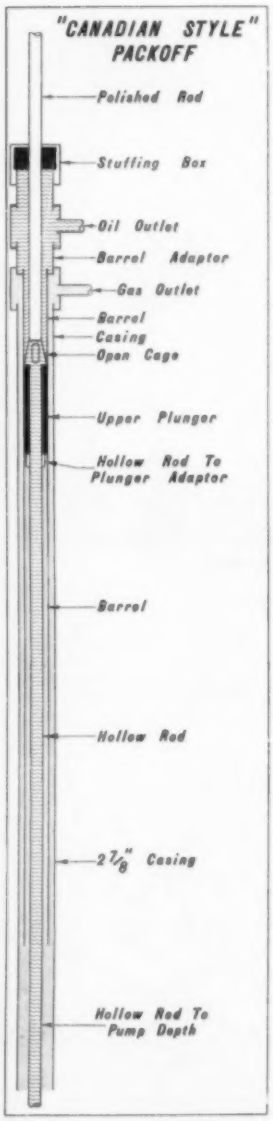


FIG. 12. "Canadian style" packoff arrangement incorporates a standard polished rod and eliminates reciprocating oil outlet.

Example Calculations

In order to size an installation initially, a series of charts is provided (Fig. 6 to 9) to allow a quick check of a proposed hollow sucker tube installation. Two things must be known: (1) depth at which the pump will be placed, and (2) the volume per day that must be produced.

The following example will illustrate the use of the charts.

Assumed conditions:
Pump depth — 4000 ft
Desired volume — 100 bbl fluid per day
Heaviest well fluid — salt water weighing 404 lb per bbl

Step 1. Select a sucker tube size: 1 in.

Step 2. From Fig. 6 at 4000 ft and above tube size, read W_r: 7200 lb

Step 3. From Fig. 7 at 4000 ft and above tube size, read W_f: 1700 lb

Step 4. $W_f + W_r$: 8900 lb

Step 5. Select a plunger size: 1¼ in.

Step 6. From Fig. 8, solve the chart for several combinations of stroke (L) and speed (N):
Combination A: 48 in. by 14 spm
Combination B: 36 in. by 18½ spm
Combination C: 54 in. by 12½ spm

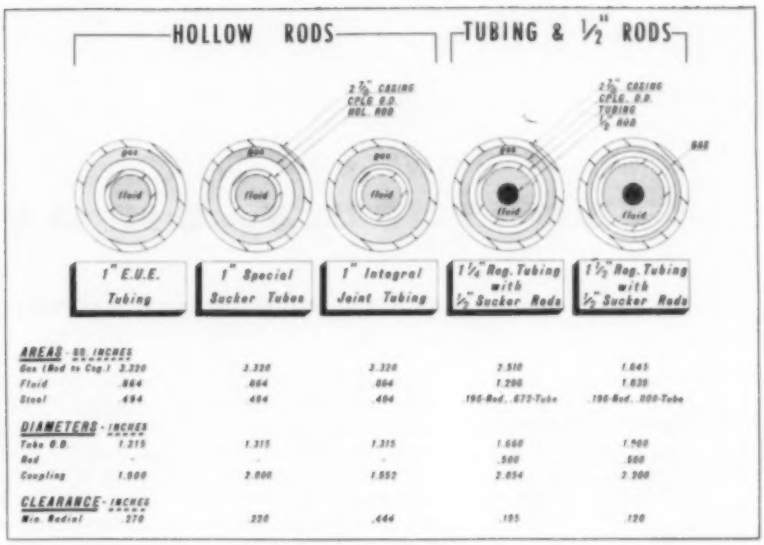

HOLLOW RODS
TUBING & ½" RODS
1" E.U.E. Tubing
1" Special Sucker Tubes
1" Integral Joint Tubing
1¼" Reg. Tubing with ½" Sucker Rods
1½" Reg. Tubing with ½" Sucker Rods
AREAS - SQ. INCHES
Gas (Rod vs Csg.) 3.320 3.320 3.320 2.510 1.845
Fluid .864 .864 .864 1.296 1.639
Steel .494 .494 .494 .196-Rod, .673-Tube .196-Rod, .800-Tube
DIAMETERS - INCHES
Tube O.D. 1.315 1.315 1.315 1.660 1.900
Rod - - - .500 .500
Coupling 1.900 2.000 1.852 2.054 2.200
CLEARANCE - INCHES
Min. Radial .270 .220 .444 .195 .120

FIG. 13. Cross sections of downhole equipment in several types of slim-hole pumping installations illustrate areas and clearances.

Step 7. From Fig. 9, solve for "C" for each of the combinations in Step 6 by drawing a straight line from "L" through "N" and reading "C" at intersection of line with the left scale:

"C" for Combination A: 0.120
"C" for Combination B: 0.175
"C" for Combination C: 0.132

Step 8. Add 1.00 to "C" for each combination and multiply the total by $(W_r + W_r)$ from Step 4.
This value is the peak polished rod load (PPRL):

PPRL for Combination A: 9,970
PPRL for Combination B: 10.450
PPRL for Combination C: 11,750

Step 9. Compute MPRL from the equation
$MPRL = W_r(1 - C) - (A_p - A_r)(psi/ft)(depth)(1 + C)$, selecting values of $A_p - A_r$ from the following table and using 0.500 for gradient of fluid:

Common Values of $A_p - A_r$

Tube Size	Plunger Size – in.					
	¾	⅞	1	1 1/16	1¼	1½
¾	–0.091	0.075	0.252	0.354	0.697	1.237
1	–0.422	–0.256	–0.079	0.023	0.366	0.906
1¼	–1.053	–0.887	–0.710	–0.608	–0.265	0.275

MPRL for Combination A: 5520
MPRL for Combination B: 5085
MPRL for Combination C: 5410

Step 10. Determine the load range for subtracting the load found in Step 9 from the load found in Step 8 for each combination. The speed-stroke combination with the minimum load range is the best choice:

Load range for Combination A: 4450
Load range for Combination B: 5365
Load range for Combination C: 6340

Step 11. Using Fig. 10, find the stress in the sucker tube wall at peak load. If this value exceeds 28,000 to 30,000 psi, re-examine the design. In most cases the computed PPRL will be higher than actually measured, meaning that the stress will not reach 30,000 psi in practice.

From a stress and load-range standpoint, Combination A appears best. However, the beam unit required for Combination B may in some cases be somewhat cheaper and some operators would prefer the less expensive installation.

This method of sizing installations will give adequate values for PPRL and MPRL. From this information, peak torque can be estimated and the gear box then sized. The last step, of course, is to estimate the installation cost.

Typical Installations

Basically, there are two ways to install a surface packoff on a hollow rod pumping installation. Fig. 11 and 12 show schematic details of each. The "Borger style," developed in the Texas Panhandle, is the cheaper and probably the easier to rig up. It provides a continuous flow path for fluids coming up the hollow rod. The "Canadian style" incorporates a chamber which changes volume during each stroke. There is some evidence that this fluctuating chamber may interrupt the flowing characteristics of a producing well.

Use of beam type pumping units leaves open the choice of packoff arrangements. If the well is to be produced using a hydraulic unit, however, the "Canadian style" is indicated.

Size of the components of any pumping installation is important. Such things as radial clearances for overshots, coupling diameters, gas and fluid areas, and wall thicknesses must be considered. Fig. 13 presents a drawn-to-scale diagram of the down-hole equipment involved in various slim hole pumping installations. It is apparent that a fishing job in the tubing and rods installation could be much more difficult than a comparable job in the hollow rod installation.

References

1. Sucker Rod Handbook, Bethlehem Steel Handbook 489, 1948, p. 127.

2. McDannold, G. R., Vinson Supply Company, *Calculated Polish Rod Loads for Wells Using Macaroni Sucker Tubes.*

3. Hardy, A. A., W. C. Norris Company, memorandum dated December 10, 1959.

4. Erskine, R. M., Continental-Emsco Company, *Slim Hole Completions — Planned Selection of Pumping Equipment*, API Meeting, April 1, 1960, Wichita, Kansas.

5. Spang Engineering Data, June, 1950, pp. 40-100.

★ ★ ★

U.S. OIL RESOURCES:

PAUL D. TORREY, *The University of Texas, Austin, Texas*

"... the United States can be reasonably self-sufficient in its oil requirements in the foreseeable future" if we apply improved secondary recovery methods and essential conservation measures

FUTURE RECOVERY from existing oil fields in the United States may be as much as 90 billion bbl. This is one of the major conclusions in the present report made by the Secondary Recovery and Pressure Maintenance Committee to the Interstate Oil Compact Commission. This study, the fourth of its kind made by the Committee, is believed to be the only one that estimates the amount of oil that existed originally in the reservoirs in addition to estimates of additional oil that can be obtained by the application of fluid injection methods.

Previously, the Committee has considered only oil that is susceptible to recovery by primary methods and by conventional methods of gas and water injection. This year, however, the Committee has considered the additional oil that may be obtained by new processes, such as thermal recovery and solvent extraction, even though it is recognized that there are still uncertainties connected with the possible extent to which these new processes may be applied and with the measure of their effectiveness.

Alaska included. No new states have been added individually to the schedule

TABLE 1.
Oil Resources of the United States as of January 1, 1960.
(All figures in millions of barrels of 42 U.S. gallons.)

State	(1) Estimation of original oil content of reservoirs	(2) Total oil production to 1/1/60	(3) 1959 oil production API figures	(4) API proved reserves from volume 14(A)	(5) IOCC proved reserves as of 1/1/60	(6) Estimated additional reserves physically recoverable by known improved recovery methods	(7) Additional reserves recoverable by conventional gas and water injection water conditions existing as of 1/1/60
New York	743	206	2	34	0	210	25
Pennsylvania	3,831	1,215	6	114	27	1,018	113
West Virginia	2,593	462	2	51	37	590	14
Kentucky	1,470	397	28	136	160	450	65
Ohio	4,592	661	6	74	61	376	7
Indiana	3,003	305	12	74	40	280	100
Illinois	7,352	2,154	77	594	335	3,110	810
Michigan	1,573	426	11	55	58	357	109
North Dakota	2,751	82	18	382	465	606	141
Nebraska	1,082	118	23	81	83	125	55
Kansas	15,450	3,196	119	917	825	1,500	125
Oklahoma	48,215	8,019	193	1,865	1,459	4,540	1,369
Arkansas	5,596	1,081	25	313	255	342	171
Alabama	358	30	6	34	69	111	111
Mississippi	3,307	634	47	389	661	1,322	150
Louisiana (B)	23,662	4,859	318	4,660	4,275	1,659	2,730
Texas (B)	112,106	22,906	939	14,860	15,528	16,046	4,958
New Mexico	9,960	1,376	102	1,026	887	3,984	996
Colorado	3,217	552	46	381	214	1,210	624
Wyoming	10,997	1,781	125	1,403	1,191	1,272	556
Montana	2,689	334	30	309	335	155	64
Utah	1,725	82	40	195	232	607	527
California	62,048	11,750	307	3,763	3,763	4,113	1,000
Other States (C)	87	10	1	9	10	30	2
Total	328,407	62,636	2,483	31,719	30,970	44,013 (D)	14,822
Change from 1-1-58	+18,500	+ 4,818	− 76 (E)	+ 1,419	+ 390	+ 9,530 (D)	+ 1,727

Footnotes:
(A) American Petroleum Institute and American Gas Association, "Proved Reserves of Crude Oil, Natural Gas Liquids and Natural Gas." December 31, 1959, Volume 14.
(B) Includes offshore reserves
(C) Includes Alaska, Arizona, Florida, Missouri, Nevada, South Dakota, Tennessee, Virginia, and Washington.
(D) In 1958 recovery by means of solvents and heat was not considered.
(E) Change from 1957 to 1959 Production.

PAST, PRESENT, AND FUTURE

in Table 1 since the last report. However, Alaska has been added to "Other States" even though little is known about its oil resources. Similarly, it is difficult to appraise the potential of some of the other states with recent discoveries. All figures relating to oil reserves are changed from time to time as new fields are discovered or as more information is obtained about existing fields, and Alaska will probably not prove to be an exception.

The statistics presented in Table 1 parallel, except for column 6, rather closely those presented two years ago at the mid-year meeting of the Compact at Salt Lake City, Utah.[1] Increases can be expected in original oil in place (column 1) as more oil is found and in total oil produced (column 2) as production has been maintained. However, oil production was lower in both 1958 and 1959 than in 1957 (column 3). Texas oil production dropped below 1 billion bbl in both 1958 and 1959. In 1959 Louisiana advanced ahead of California for the first time as the second largest oil producing state.

The 1959 production of the 10 most important states along with their API proved reserves in numerical order are listed in Table 2.

Reserves at all-time high. After declining in 1957 from a previously established high in the preceding year, API proved reserves increased moderately in 1958 and substantially in 1959 to an all time high of 31,719 million bbl.[2] From the preceding tabulation it will be seen that the rank of the states in reserves corresponds with their rank in oil production except that the position of Kansas and New Mexico is reversed.

API proved reserves have advanced continually, except in 1957, in every post World War II year up to the present. The estimated proved reserves at the end of each year and the increase over the previous year is given in Table 3.

Presented at the 1960 Mid-Year Meeting of Interstate Oil Compact Commission, Detroit, Michigan, June 13-15, 1960.

It is notable that the big increase in reserves took place in the period from 1946 through 1955 during which period the average annual increase amounted to almost 1 billion bbl. Thereafter, the advance in reserves has been at a much more moderate rate except during 1959. This decline in the rate of reserve build up cannot be attributed to any inability on the part of the domestic industry to find and produce oil. Rather it results directly from a substantial decrease in exploration and drilling activity which can be expected to continue as long as operators do not have adequate incentive to look for new oil fields.

New states join list. API proved reserves increased from 1957 to 1959 in Ohio, Indiana, Michigan, North Dakota, Nebraska, Arkansas, Mississippi, Louisiana, Texas, New Mexico, Colorado, Utah, and California. Some new oil has been found in Ohio, Indiana, and Michigan during the past two years. The most significant increases in proved reserves have been in North Dakota and Nebraska which have resulted from important new discoveries and from the wise application of pressure maintenance to existing reservoirs; in Louisiana from major offshore developments; and in the mountain states where exploration for new fields has been going on at a high level of activity. Mississippi improved its position moderately, and Arkansas, California, and Texas barely maintained their past position.

Although crude oil reserves have increased substantially in the United States in post World War II years the increase in this country has been mediocre compared to other parts of the world. Tables 4 and 5, developed in large part from the 1947 World Oil Atlas[3] and from the most recent World Wide Report[4] show this spectacular comparison.

The oil reserves in 1946 and 1959 of the most important oil countries are listed in Table 5.

The significance of these figures will be even more apparent from Fig. 1.

U. S.: from first to fourth. From the data in Table 5 and from Fig. 1 it can be seen that the United States has dropped from first to fourth place in the world's crude oil reserve picture in a period of only 14 years and during this period its percent increase in reserves was less than any of the other countries considered. It is pertinent to note that during this same period Soviet

TABLE 2. 1959 Oil Production and API Proved Reserves of the 10 Most Important States.

State	Production — million bbl	Reserves — million bbl
Texas	939	14,860
Louisiana	318	4,660
California	307	3,763
Oklahoma	193	1,865
Wyoming	125	1,403
Kansas	119	917
New Mexico	102	1,026
Illinois	77	594
Mississippi	47	389
Colorado	46	381

TABLE 3. API Proved Reserves in Post World War II Years.

Year	Reserves — million bbl	Increase over Previous Year — million bbl
1946	20,874	932
1947	21,488	614
1948	23,280	1792
1949	24,649	1369
1950	25,268	619
1951	27,468	2200
1952	27,961	493
1953	28,945	984
1954	29,561	616
1955	30,012	451
1956	30,435	423
1957	30,300	—135
1958	30,536	236
1959	31,719	1183

TABLE 4. World Proved Reserves in 1946 and 1959.

Area	Proved Reserves — billion bbl 1946	1959
North America	21.9	37.7
South America	8.3	21.9
Europe	0.3	1.5
Africa	0.2	7.3
Middle East	27.3	181.4
Far East	1.2	10.2
Russia and Satellites	7.9	30.1
Total	67.1	290.1

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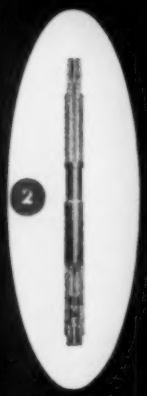

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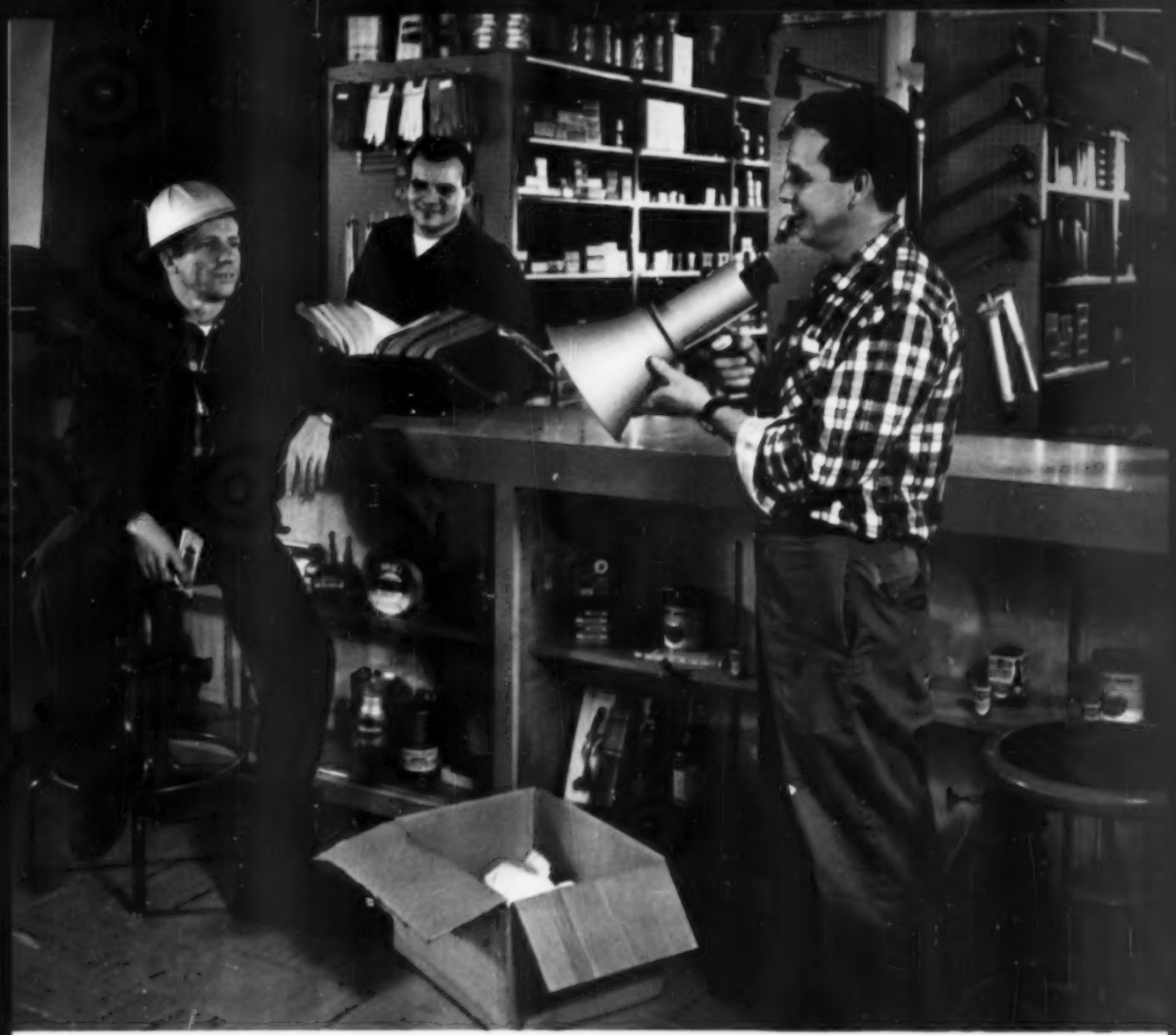

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Russia found almost twice the amount of new reserves as the United States did even though it dropped from third to fifth ranking position. Even if we consider that all of the Western Hemisphere's reserves, amounting to some 59.6 billion bbl, might be available to the United States in an emergency, this is only about one-third of the proved reserves in the Near East alone and amounts to only about one-fifth of the total proved reserves of the world. It is obvious that the United States proved oil reserve position has deteriorated seriously in the post World War II period.

Fluid injection important. The important part that fluid injection operations will have in future oil production in various states is very apparent from Table 1. Actually the economically recoverable reserves by gas and water injection methods are greater than the primary reserves in New York, Pennsylvania, Indiana, Illinois, Michigan, Alabama, New Mexico, Colorado and Utah and they are approximately equivalent in Oklahoma. It can be seen from this table that the proved recoverable oil reserves of the nation, as a result of the development and application of gas and water injection methods, are in the range of some 45.8 billion bbl of crude oil (column 5 plus column 7 of Table 1) rather than some 31.7 billion bbl as estimated by others. This represents a very significant increase of 44.4 percent.

As was the case in previous reports, the estimated primary reserves are very close to the estimation by the API Committee of the proved reserves. However, if the Compact Committee's primary reserves are added to its economically recoverable fluid injection reserves, the sum is considerably greater than the API proved reserves.

As new oil fields are found the original oil content of the known reservoirs is increased. The Compact Committee estimates that this original oil content has amounted to the impressive figure of 328,407 million bbl (column 1 of Table 1). No one can deny the abun-

TABLE 5.
Proved Oil Reserves and Rank of the Most Important Countries in 1946 and 1959.

	1946			1959				
Country	Proved reserves—billion bbl	Rank	Percent of world reserves	Proved reserves—billion bbl	Rank	Percent of world reserves	Increase over 1946	
							Billion bbl	%
United States	20.9	1	31.1	31.7	4	10.9	10.8	51.7
Kuwait	9.0	2	13.4	62.0	1	21.4	53.0	588.8
USSR	7.5	3	11.2	28.0	5	9.7	20.5	365.9
Venezuela	7.4	4	11.0	18.0	7	6.2	10.6	143.2
Iran	7.0	5	10.4	35.0	3	12.1	28.0	400.0
Saudi Arabia	5.4	6	8.1	50.0	2	17.2	44.6	825.9
Iraq	5.0	7	7.5	25.0	6	8.6	20.0	400.0
Indonesia	0.8	8	1.2	9.0	8	3.1	8.2	1025.0
North Africa	0.2	9	0.3	7.3	9	2.5	7.1	3550.0
Canada	0.2	10	0.3	3.5	10	1.2	3.3	1650.0
Rest of world	3.7		5.5	20.6		7.1	16.9	563.3
Total	67.1		100.0	290.1		100.0	223.0	

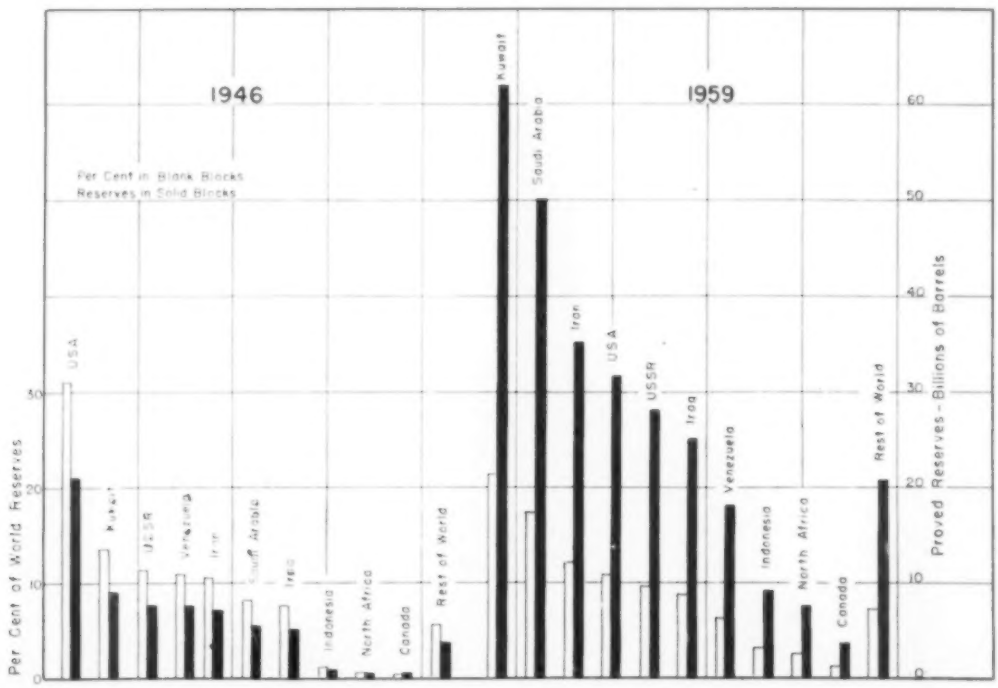
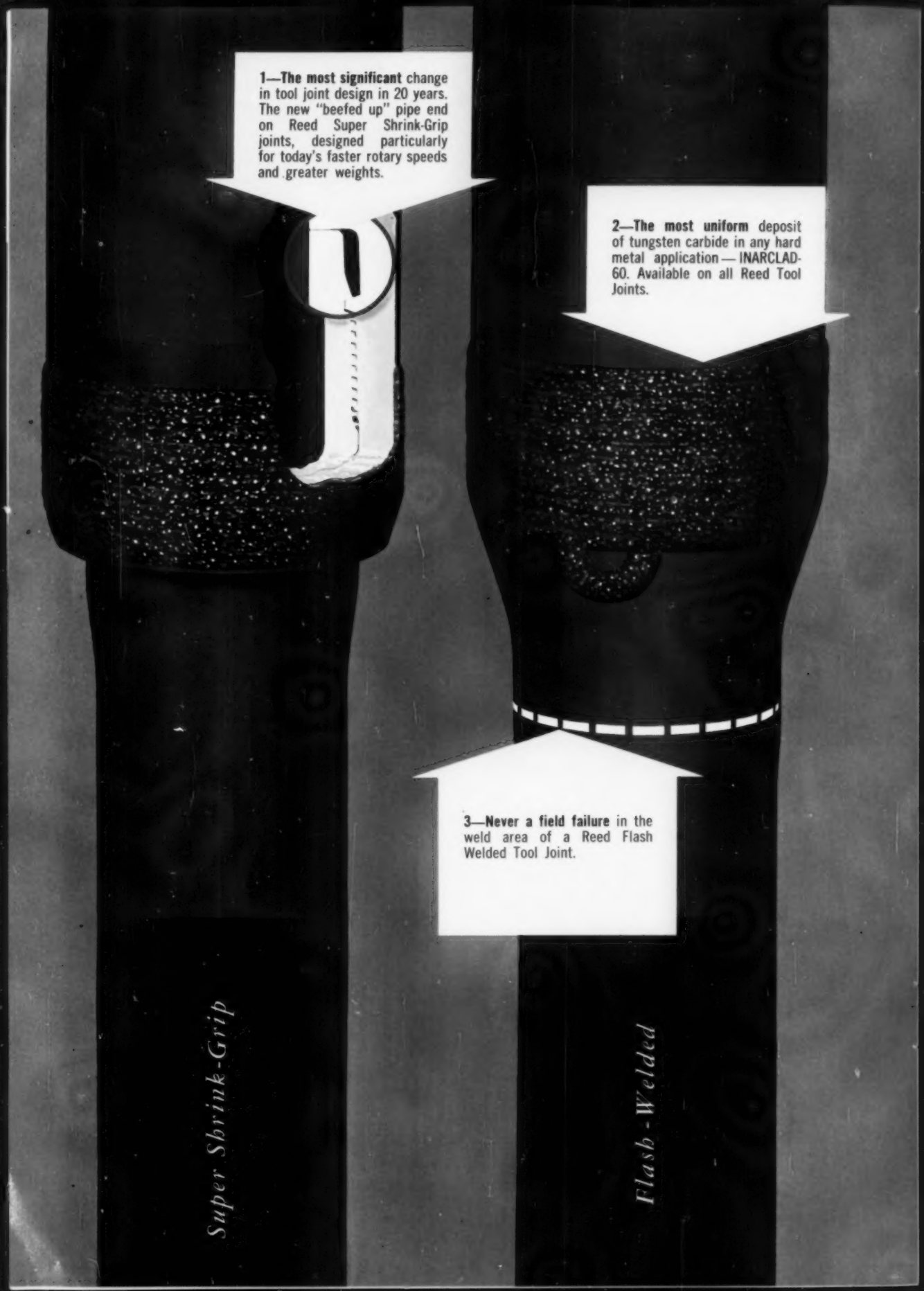


FIG. 1. Distribution of world oil reserves in 1946 and 1959.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dance with which the United States has been supplied with liquid hydrocarbons.

If the combined primary reserves (column 5 of Table 1) and the reserves that will be obtained by conventional gas and water injection (column 7 of Table 1) are added to the past production of the oil fields of the United States (column 2 of Table 1), it will be seen that the known fields of the nation will produce eventually about 108.4 billion bbl of oil, which amounts to 33 percent of the original oil in place. Although this percentage of recovery is much less than that obtained by certain other mineral industries, it represents a great improvement over the recovery that was obtained from oil fields only a few decades ago. Nevertheless, the 220 billion bbl that will not be recovered under existing conditions presents a challenging problem.

As an example of the great growth that has taken place in the number of water injection projects in the United States, the number and the oil production resulting from them for the past 25 years is shown graphically in Fig. 2. Further increases in oil production can be anticipated in 1960 and in succeeding years as results begin to appear from large pressure maintenance projects in the Wilmington field in California, the Rangely field in Colorado, and other fields.

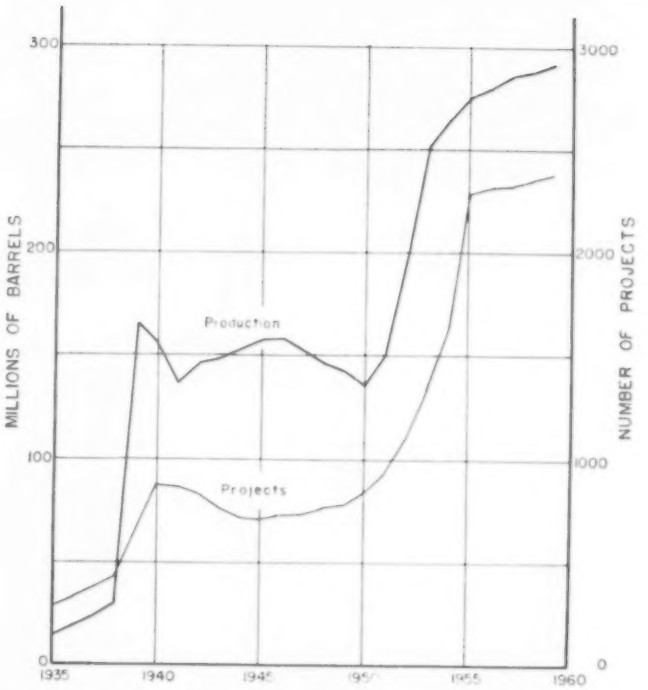

FIG. 2. Number of projects and oil production from water injection fields in the U. S. (After Dahlgren,[5] Sweeney,[6] and Torrey.)

Secondary recovery oil. As mentioned previously, the Committee for the first time this year has considered the oil that is physically recoverable by other known improved recovery methods which, heretofore, have not been considered. Its preliminary estimation of the oil reserves that may be produced by solvents such as alcohols, the miscible phase displacement and other forms of high pressure gas injection, including the use of carbon dioxide, and by thermal methods is given in column 6 of Table 1. The Compact Committee has been fortunate to have had the benefit of information from the leading oil recovery experts on these methods such as Whorton and Dorsey,[7] Martin,[8] Russell,[9] Nelson and McNiel,[10] Morse,[11] and Slobod[12] to cite some of the esteemed experts who have contributed to the programs of various Committee meetings. The conclusion of these authorities is unanimous that under certain reservoir conditions the application of new recovery methods will result in the recovery of a substantial part of the total oil content, particularly in fields of fairly recent discovery.

In considering how these new methods may be employed the Committee has recognized, just as it did in considering first the possible effects of conventional gas and water injection,[13] that future developments and studies will necessitate recalculations and revisions of its present findings. Where little or no field experience is available, such as is the case in Arkansas, Louisiana, and Alabama, the contributors to the Committee's study have hesitated to estimate large reserves attributable to the new methods. However, in course of time they may prove to be highly important in maintaining oil production in these and in other states.

The large reserve by new improved recovery methods estimated for Texas may be questioned. It has been developed by a review of most of the state's fields which possess at least one-half of their initial reservoir pressure. If this reserve of slightly over 16 million bbl is added to past production and future recovery by primary and conventional secondary methods the possible ultimate recovery from Texas fields is still only a little over one-half of the original oil in place in the reservoirs of the state.

Inventory: 90 billion bbl. Regardless of all the geologic, legal, and economic problems that may affect the future application of the new recovery methods to the oil fields of the United States, the thought may be expressed that the present estimation of some 44 billion bbl that may be so obtained is actually a minimum figure and may be expanded substantially in the future. The future recovery expectancy from existing United States oil fields, therefore, could be in the range of 90 billion bbl rather than around 45 billion bbl, and if this figure should be used for the year 1959 in Fig. 1 the rank of this country would return to the prominent position it occupied in 1946. Of course, it can be said that the same new methods could be equally successful in many foreign fields.

Although figures from 1959 are not yet available, it is a reasonable supposition that about 3.5 billion bbl of the economically recoverable reserves by conventional methods of fluid injection exist in stripper well fields; that is, in fields where the cost of production equals or is approaching the value of the oil produced. Recent studies have shown that almost three-quarters of all of the oil wells in the United States are in the stripper or marginal classification.

The oil reserves in the stripper fields are particularly precious to the United States, because many of them were discovered several decades ago when the cost of finding, developing, and operating oil fields was much less than it is at the present time. If these old wells should be abandoned for any reason, such as a lack of market for the crude oil they produce, manifestly, it might be unprofitable to drill new wells and install new equipment, at a cost that might be four times the original development cost, even though proved

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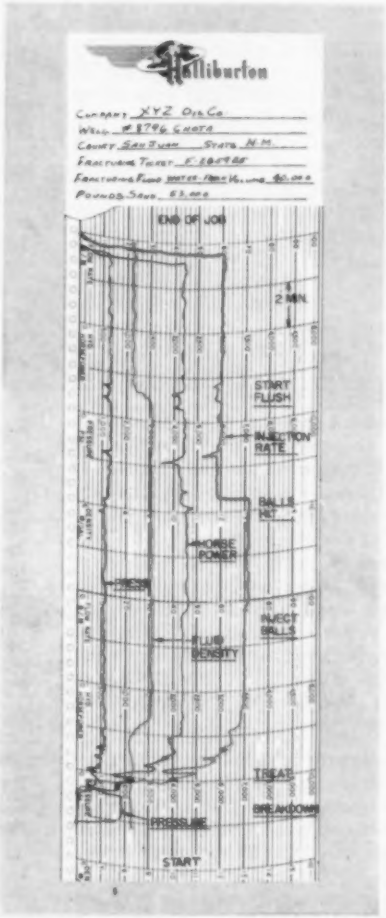

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secondary reserves of large size are known to be present.

U. S. self-sufficient. Much of the preceding discussion has been developed to assure the Compact that the United States can be reasonably self sufficient in its oil requirements in the foreseeable future. The writer's contentions in this regard are supported convincingly by Morgan J. Davis, a distinguished geologist in addition to being the president of the largest domestic oil producing company.[15] Davis has emphasized the difficulties that have been experienced in the past in the estimation of the ultimate oil production to be realized in the United States. He has expressed the opinion that during the next 20 years a minimum of some 70 million bbl of additional oil supplies, in addition to the existing proved reserves, will be available. He believes that from 20 to 25 billion bbl will come through developing and extending known fields and in improving the primary methods used in them; some 20 million bbl will come through improved secondary recovery in projects not yet commenced; and some 35 million bbl will come through the exploration of untested prospects already located and from undeveloped areas now under lease.[16] These figures seem very realistic by reason of the evidence developed by the Compact Committee.

General Ernest O. Thompson,[17] former chairman of the Interstate Oil Compact Commission and a member of the Railroad Commission of Texas, has emphasized that the only way the nation's reserves can be maintained and utilized on a safe basis is by means of a virile, prosperous, domestic oil-producing industry. He considers it essential to keep the United States from becoming increasingly dependent upon foreign crude oil for our national security and for the well-being of the nation.

Conservation of extreme importance. The effect that the adoption of conservation measures has had on the application of improved technology to the recovery of oil has already been emphasized. Similarly, there now appears to be fabulous opportunities for the Compact to encourage the enactment of laws and the promulgation of regulations suitable to the conditions existing in its respective member states that will enable the industry to take advantage of economies in development and production practice which American technical ability has made possible.

It is not within the scope of this report or it is not a part of the Committee's responsibility to deal with the legal aspects of conservation. Its assigned responsibility has been to develop convincing evidence that there is an abundance of oil in the United States and to show that ways whereby greatly increased recovery can be obtained have been demonstrated. At the same time it must be emphasized that present economic conditions in the industry make it imperative that the future production of oil be less expensive as well as more efficient to enable domestic operators to compete successfully with foreign fields where there are relatively few wells which produce at high rates. To achieve this objective there seems to be no other effective alternative plan to compulsory unitization laws which have been opposed successfully by various legislatures in past years.

Recently the industry has had reason to be encouraged by the orders of two regulatory bodies and by a court decision which have been based on engineering evidence and which will serve to prevent a lot of wasteful and unnecessary drilling. Orders by authorities in North Dakota, Utah, and a decision by the Supreme Court of Michigan are of significant importance and indicate a developing understanding that tightly spaced wells are not essential in most fields for the efficient recovery of oil. Recognition of this fact by the executives and legislatures of other states should result in tremendous benefit to the entire industry.

The order of the North Dakota Commission on the Rough Rider field[18] represents real progress in regulation of oil field development for it permits a temporary spacing of one well to 320 acres and it expresses the belief that such wide spacing will result in an efficient and economical development of the field and will serve to avoid the drilling of unnecessary wells.

The recent order of the Utah Oil and Gas Conservation Commission establishing 80-acre well spacing in the Aneth field.[19]

In somewhat paralleling action, the Supreme Court of Michigan, in the Burdell Oil Company case,[19] supported the decision of the state's Supervisor of Wells to refuse permission to drill wells on tracts of smaller size than the spacing established for the field.

Also, a hearing was recently called by the Honorable Ashton Mouton, Commissioner of Conservation of the State of Louisiana, to consider a proposal to increase Louisiana's basic well spacing from 40 to 80 acres. This is further evidence of growing consideration that is being given to the development of oil fields, and it is particularly encouraging that such consideration is taking place in Louisiana, the second most important oil state.

In concluding this consideration of United States oil resources, and how they can be made available, it is pertinent to mention how closely the Committee's findings conform to the study by Bruce C. Netschert[20] who, like Morgan Davis, has recognized the tremendous impact that technological advances are going to have on the future availability of crude oil in the United States. Such conclusions are certainly confirmed by the phenomenal growth in the production of oil from fluid injection projects in United States fields, that has taken place in post World War II years. In fact, outside of the actual discovery of oil reserves, the development and application of fluid injection methods certainly ranks as the most important single factor in the maintenance of the oil industry in many of the states.

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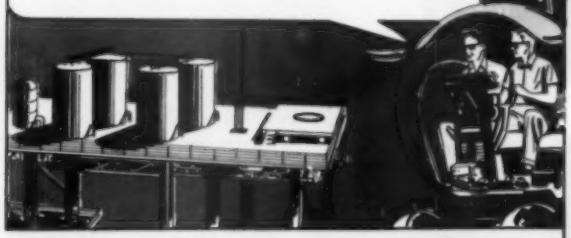
★ ★ ★

1.

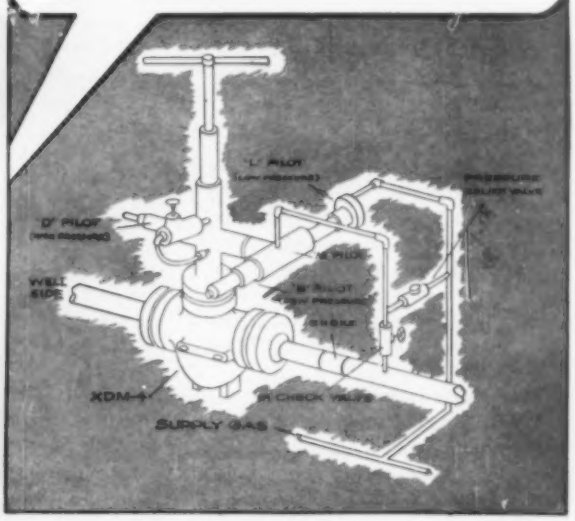
OTIS SURFACE SAFETY VALVES

—equipped with automatic pilots—shut in the six wells on this platform and PREVENTED A MAJOR FIRE that could have cost us several million dollars.



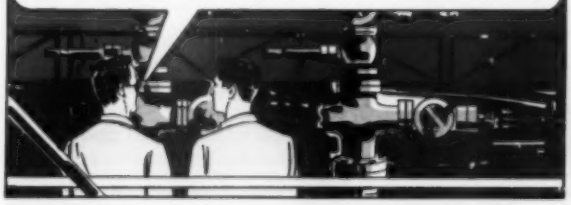
2.

Here's a diagram of the safety valve and automatic pilot installation we had on this platform. Each of the six wells had a Type XDM-4 Otis Surface Safety Valve installed between the wing valve and the choke. The safety valves and pilots were installed so as to (1) shut in an individual well should a freezing condition exist in a flow line or choke; (2) shut in all wells on the platform should a flow line break, or (3) shut in all wells on the platform should the gas sales line break, or should something happen to any of the auxiliary equipment on the platform. In this case it was high temperature on a heater that activated a Type L Otis Pilot to shut in all the wells.



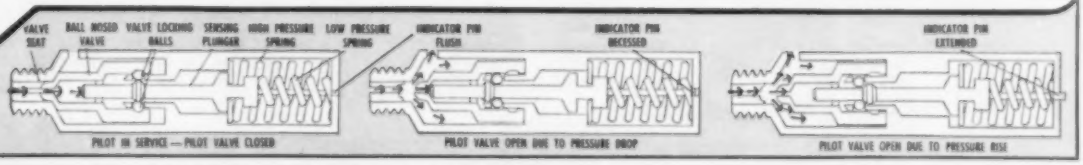
3.

The six wells were producing 32 M.M.C.F.D. when an equipment failure boosted the temperature in one of the heaters to about 1,000° F. This set the platform on fire. But we didn't lose our wells or the platform—thanks to the Otis Safety Valves. When our pumper got out here he found all of the wells shut in, and only a small fire burning, which he extinguished. After making minor repairs, the safety valves and pilots were reset and the wells put back on production.



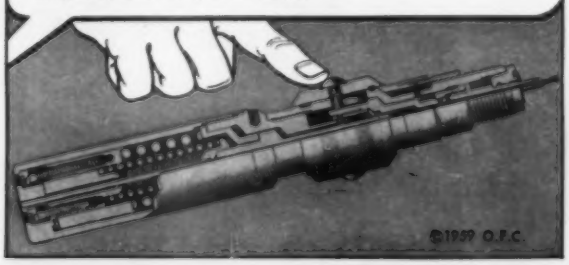
4.

Speaking of resetting pilots, have you seen the new Type E Otis Hi-Lo Pilot? It's so simple to set and reset a boy could do it. These schematic diagrams show the pilot in its three operating positions: set and ready to operate; opened as a result of a pressure drop; opened as a result of a pressure rise. The new Type E pilot has many features we like. To list a few—it's quiet. There's no loud pop when it opens. The standard model is rated to 8,000 P.S.I. and we can get higher pressure ratings on special order. The Type E is adaptable to remote control or external control systems using electricity, hydraulic pressure, or microwave. You can trip the pilot manually without any special tools. We've found the pilot accurate to plus or minus 1%. It has a visual indicator to tell you when the pilot is locked out of service, and another indicator to tell you whether the pilot operated due to a pressure rise or drop.



5.

To get back to resetting the Type E Otis Hi-Lo Pilot—here's all you do. After the pilot has operated you twist this reset collar to the right. This closes the pilot and exposes a red band, which is a visual indication that the pilot is locked out of service. When the indicator pin is flush with the end of the pilot you can put the well back on production by twisting the reset collar to the left. We'll be using a lot of these pilots in the future because of their simplicity and many advantages.



6.

The Otis Surface Safety Valves and Pilots we installed on our platform only cost $6,500. That's a pretty small investment to protect a several-million-dollar installation. And this isn't the first time Otis safety equipment has saved us a substantial loss. Experience has taught us we can rely on Otis safety equipment. If you have ANY UNPROTECTED WELLS—especially in isolated locations or in critical areas—I suggest you call your nearest Otis office now. Let an Otis safety valve expert help you work up the proper safety program for your wells—TODAY—BEFORE YOU NEED IT.

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What's doing in DRILLING

First Mobile Unit Aided By Tender Scheduled

First tender-assisted mobile drilling platform to work in Lake Maracaibo will soon go into operation under close scrutiny of the Venezuelan oil industry.

New first-of-its-class unit, which may cut substantially the cost of finding and producing oil, has been purchased by Loffland Brothers Company, Tulsa drilling contractor. Mobile drilling platform will be built at Vicksburg, Mississippi, and towed to Venezuela, where it will be used in drilling for Mene Grande Oil Company.

Three-legged platform, which can be used in water 105 ft deep, will operate with one of Loffland's tenders now in Venezuela. The multi-purpose unit can be used for stratographic survey, exploration and production, drilling and workover.

photo courtesy R. G. Le Tourneau

In workover service, it can be used on existing wells with wide variations in production platform designs and sizes. Unit will be floated into position with the larger-than-normal drilling slot enveloping the platform.

Electrically-powered legs will be lowered to the bottom and the platform elevated above the water. Derrick and its equipment, which can be skidded fore and aft and athwartship by electric gear motors, will then be moved into place over the wellhead. Precise positioning of the half-million pound load thus becomes a pushbutton operation.

Tender-assisted mobile drilling platforms, which have been used in other parts of the world, have never operated in Lake Maracaibo because of the soft mud bottom. However, a construction mobile platform similar to those used in drilling was recently placed in service in the lake and demonstrated that platforms of this type could operate there.

Largest Shipment Made Of Equipment To India

Largest shipment of oil well drilling equipment from the United States to India has been made. Shipment includes two trailer-mounted drilling rigs, complete with 97 ft masts and power

Optional racking platform to fold up or down
Optional hydraulic or wire line casing and telescoping mast
Optional pole masts
Optional axles
Optional single or dual engines and compound
Torque converter, transmission, or both
Buy your self-propelled unit built the way you want it —
Design your own rig, and have it built from standard parts!
Look at these options . . .

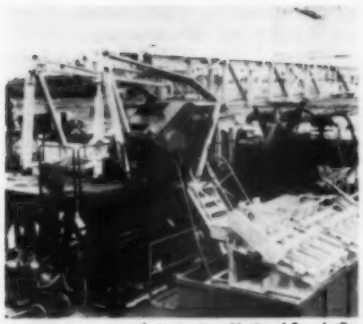

photo courtesy National Supply Co.

equipment, drill pipe, and 66,800 ft of steel casing.

Most of the machinery and equipment was manufactured in Torrance, California, and Gainesville, Texas. Pipe was produced in the seamless tubular mill at Ambridge, Pennsylvania. Rigs, which also included components from other manufacturers, were rigged-up and test assembled at Houston and then shipped.

Rigs are normally used for drilling in the 4500 to 7500 ft depth range. Equipment for each rig includes drawworks, rotary machine, swivel, hookblock, two slush pumps, and an independent pump drive for use with one of them.

Shipment also includes three diesel engines, two for powering the rig and one for the independent slush pump, a mast and single trailer assembly mounted on tracks to be drawn by a tractor.

Casing shipped includes 52,800 ft of 5½ in., 12,800 ft of 9⅝ in., and 1200 ft of 13⅜ in., all API Casing. Other tubular products shipped were 16 drill collars, each 4¾ in. diam by 30 ft, and 14,000 of 3½ in. drill pipe with tool joints.

M. S. Ram, director of the India Supply Mission, inspected the equipment at the rig-up yard. On arrival at Bombay, India, the material will be carried by railroad to the drilling area near Cambay.

Rotary Rigs Operating in Oil Fields of United States and Canada

As reported to American Association of Oil Well Drilling Contractors by Hughes Tool Company.

	May 2	May 9	May 16	May 23
Alabama	3	5	5	5
Alaska	5	5	5	5
Arkansas	11	12	11	11
Arizona	3	2	1	2
California—Land	91	91	93	94
California—Offshore	5	5	5	6
Calif.—Total	96	96	98	100
Colorado	28	25	25	28
Florida—Land	0	1	1	1
Florida—Offshore	1	0	0	0
Florida—Total	1	1	1	1
Illinois	54	48	47	52
Indiana	9	10	6	8
Iowa	0	0	0	0
Kansas	115	117	122	138
Kentucky	6	4	4	5
North Louisiana	33	33	40	41
South Louisiana—				
Inland Waters	112	112	116	113
South Louisiana—				
Land	79	75	75	80
South Louisiana—				
Offshore	57	53	50	54
Louisiana—Total	280	273	281	288
Maryland	0	0	0	0
Michigan	29	35	38	42
Mississippi	70	57	55	64
Missouri	1	2	2	3
Montana	20	14	20	20
Nebraska	20	23	28	24

	May 2	May 9	May 16	May 23
Nevada	0	0	0	0
New Mexico	122	124	113	119
New York	1	1	1	1
North Dakota	14	13	15	20
Ohio	4	4	4	5
Oklahoma	191	184	171	193
Oregon	0	1	1	1
Pennsylvania	15	12	11	10
South Dakota	0	0	0	1
S. Tex. & Gulf C.—				
Inland Waters	11	11	8	7
S. Tex. & Gulf C.—				
Land	156	162	177	177
S. Tex. & Gulf C.—				
Offshore	1	1	1	1
North Texas	43	43	41	44
Panhandle	50	49	53	52
East Texas	61	63	62	62
West Central Texas	188	196	204	199
West Texas	119	107	108	113
Texas—Total	629	632	655	655
Utah	24	25	26	31
Washington	0	0	0	0
West Virginia	3	3	3	4
Wyoming	55	59	62	59
Total—U. S.	1809	1787	1812	1895
Western Canada	85	92	119	129
Eastern Canada	2	2	2	2
Grand Total	1896	1881	1933	2026

Another plus value:

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Seeco-Mul Also Affords Faster Penetration, Extends Life of Bits, Collars, and Liners

On your next well, try Seeco-Mul Drilling Mud Additive as an extreme pressure additive. Many operators have recently discovered this extra advantage in Seeco-Mul; in fact we can show you data on a number of field wells drilled under almost identical conditions that will convince you that Seeco-Mul is the most effective E-P agent you can use.

The efficiency of Seeco-Mul as an E-P agent is due to its chemical structure — the ability of one end of the Seeco-Mul molecule to adhere tightly to a metal surface, attracting another molecule to form the familiar micelle, or the joining of two molecules at opposite ends. This layer attracts other Seeco-Mul molecules, which build up to an extremely tough lubricating film that is difficult to remove and will withstand high pressure, successfully reducing metal-to-metal contact and subsequent wear, or galling, of the bearing surfaces.[1]

In addition to the E-P qualities, you get many other advantages with Seeco-Mul. Inasmuch as Seeco-Mul is a chemical emulsifier with superior wetting abilities, it is often run in so-called "soap" drilling fluids (the addition of detergents to fresh water muds, oil-and-water, and water-clay systems) to lower the surface tension, thereby wetting the formation ahead of the bit and keeping the bit clean. Such systems also afford a faster penetration rate and aid the suspended solids to drop out in the pits.

Too, with good lubricating qualities in the mud, less drill stem torque is required, pump pressures can be lowered and more evenly sustained, and a higher velocity of the fluid on bottom can be obtained . . . all of which means longer service life for liners, collars, tool joints, drill pipe, and the bits themselves.

Add to this the longer bit runs and the consequent savings in bits and rig time and you will agree that adding Seeco-Mul to the system is an investment rather than a drilling expense.

Let us show you how you can use Seeco-Mul profitably. We'll gladly send you illustrated literature and a lab sample of Seeco-Mul, or contact your local mud dealer. You can get full particulars without obligation.

[1]*McCutcheon, John W., "Synthetic Detergents."*

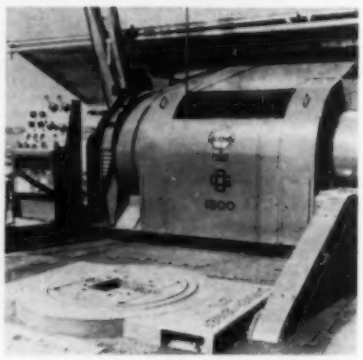
Make a good mud better . . . use

CROSSETT Seeco-Mul DRILLING MUD ADDITIVE

Manufactured by the Chemical Division of The Crossett Company, Crossett, Arkansas

Seeco-Mul is the dried flake form of a compound of the sodium salts of abietic, linoleic, and oleic acids, together with quantities of wood tannins and lignins.

Midland Drilling Contractor Buys 1500 hp Drawworks



Jones & Laughlin Supply Photo

A 1500 hp drawworks has been purchased by B. L. McFarland, Inc. of Midland, Texas. In addition to the drawworks, other major components purchased include a three-engine sectional compound, three standard oilfield power units, two 1000 hp slush pumps, and a rotary table.

New equipment will be combined with existing equipment owned by McFarland, which includes a 142 ft mast and 18 ft substructure to provide a rig capable of drilling to 20,000 ft. Acquisition of the equipment by B. L. McFarland is in accord with their program to upgrade equipment for deeper drilling and more economical operation.

Increasing competition and greater depth requirements in the contract drilling field have led many successful contractors . . . to reappraise their equipment, president of the supplying company stated. "Deeper wells and reduced profit margins demand more powerful, yet more flexible rigs," he said, "rigs that will be able to dig the deep holes and yet be able to operate economically at lesser depths are now required."

Newly-introduced single-drum drawworks has eight forward and two reverse hoisting speeds, and four forward and one reverse speed to the rotary table and catshaft. Drum capacity of the new drawworks with a 1¼ in. drilling line is 4400 ft. Cathead shaft is chain driven with a jaw clutch to permit disengaging the cathead shaft and drum drives while rotating.

The countershaft is driven by a 1¾ in. pitch double roller chain from the rotary clutch shaft and is controlled by a master clutch.

Air controls are used on the drawworks, with hand and foot throttle conveniently located at the driller's position.

The skid-mounted drawworks is 24 ft long, 9 ft, 8 in. wide and 8 ft, 1 in. high. Weight of the drawworks without accessories is about 54,000 lb.

Three-engine sectional type oilbath chain compound is equipped with 24-in. motor clutches, two 28 in. pump drive clutches, 20 "D" groove V-belt sheaves and has quintuple compounding chains, quintuple chain drive to the drawworks, and sextuple chain drive to the pump countershafts.

All chains have 1½ in. pitch. Each compound is section mounted on H beam skid frames with provisions for flanging and dowelling to adjoining sections. Lubrication is by oil pump force feed to all chains and bearings.

The standard oilfield power units are complete with radiator cooling, diesel pistons, gasoline starting engine, butane burning equipment and flywheels equipped with torque converters.

The 1000 hp duplex power slush pumps have all standard equipment including slushproof lines, pistons, valves, seats, chromeclad piston rods and quick-changed cylinder heads. Pumps have pulsation dampeners, also.

Oilbath rotary table has 2 27½ in. table opening, a 53¼ in. center distance, a 20-tooth, 2 in. pitch double rotary sprocket and an oilbath rotary drive chain guard with a 2-in. pitch double roller chain.

Positioning Of Platform Begun in California Waters

Positioning of Platform Hilda, second oil drilling structure to be erected on the Summerland state offshore lease in the Pacific southeast of Santa Barbara, California, has begun.

Standard Oil Company of California, Western Operations, Inc., will operate the lease for itself and Humble Oil & Refining Company.

The huge tower, 148 ft tall with four legs arranged in an 80 x 75 ft pattern, was towed to the site on its side and will be up-ended and settled on the ocean floor in 106 ft of water.

Hilda will be located about 1¾ miles from Hazel, the first Summerland platform, which has been in operation since summer of 1958.

New drilling platform, which will cost about $3,000,000 when completed, will have facilities for drilling up to 24 wells, two at a time if desired. It will rise 217 ft from the oceans' surface to the tops of its two derricks. Its main deck will be 120 ft square and 58 ft above water level.

Up-ending and positioning of the big new structure will be accomplished by controlled flooding of its legs. Prefabricated units of the platform superstructure and drilling equipment will be set in place with a huge derrick barge. Work will go ahead as quickly as possible, company said, with drilling operations due to begin the latter part of August.

Group Plans Building Offshore Drilling Structure

Plans for construction of an offshore oil drilling platform off Santa Barbara County, California, have been announced by Phillips Petroleum Company and Pauley Petroleum Inc. and associates.

Platform will be installed in 100 ft of water 40 miles west of Santa Barbara on the state offshore lease referred to as parcel E. Pauley-Phillips group paid the state a cash bonus of $5,100,000 for the lease in 1958.

Platform is designed for initial drilling of 33 wells, which would make it the largest offshore platform in terms of the number of wells capable of being drilled from a single structure.

Coral Drilling Elects Officers

At the annual meeting of the board of directors of Coral Drilling Company, Inc., Bob Stuard was elected a vice president of the company. Stuard has served as drilling superintendent of the company since its formation.

Officers re-elected were Ted Weiner, president; Marvin Miller, vice president; Tom Weymouth, vice president; Bob Kellerman, secretary, and Bob Johnson, secretary.

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Earl Hollandsworth, independent oil producer and president of Hollandsworth Oil Company of East Texas, was named Chief Roughneck, 1960 for the exclusive Roughnecks' Club. Founded by the Lone Star Steel Company as a dynamic symbol of the oil man's spirit, past chiefs include: **R. E. (Bob) Smith** of Houston, 1955; **Jake L. Hamon,** Dallas; 1956; **Arch A. Rowan,** Fort Worth, 1957; **Guy I. Warren,** Midland. 1958; and **J. L. (Slatz) Latimer,** Dallas, 1959.

E. Hollandsworth

S. G. Hardison

Stanley G. Hardison has been appointed Southwestern region exploration manager for Lion Oil Company, a division of Monsanto Chemical Company. With headquarters at Midland, Texas, he will direct exploration activities of the Midland, Amarillo, and Oklahoma City districts.

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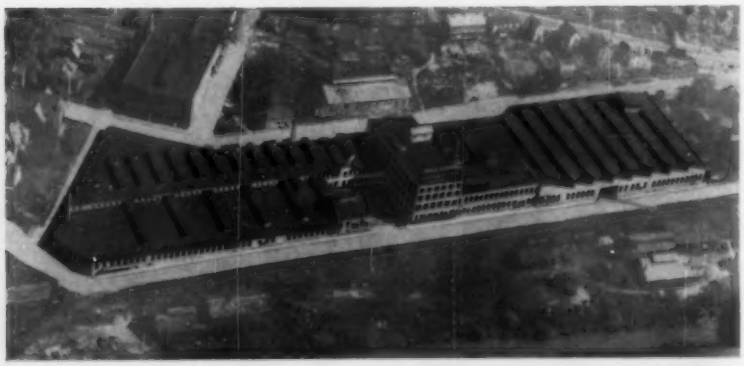

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Harold W. Owens, district geologist for the Humble Oil and Refining Company at Tallahassee, Florida, was named 1960 winner of the George C. Matson Award of American Association of Petroleum Geologists. Award committee voted unanimously in selecting Owens for the excellent presentation of his paper entitled "Florida-Bahama Platform" at the 45th AAPG annual meeting held in Atlantic City, New Jersey recently.

New TIPRO president, **John G. Hurd,** will serve as twelfth president of the Texas Independent Producers and Royalty Owners Association. The Laredo independent oil operator succeeds **Harry C. Jones** of Kilgore.

Appointment of **Richard R. Anderson** as director of production for Sun Oil Company was announced recently. He succeeds **Kingsley V. Schroeder,** who recently was named vice president in charge of domestic and Canadian production activities.

Also announced were the appointments of **J. Dwayne Taylor** as assistant to the director of foreign production operations, and **Thomas F. Ritter,** as assistant to the geological counselor for foreign operations.

J. M. Zachary was elected president of Neville G. Penrose, Inc., at a directors meeting in Fort Worth, Texas recently. **John P. McNaughton** was elected executive vice president, the post evacuated by Zachary. **Glenn G. Neill** was elected assistant vice president, **Clem L. Ware,** Midland, Texas, was elected assistant to vice president. **J. L. Tatum** was named a director. **Neville G. Penrose,** who has served as president since 1936 of Neville G. Penrose, Inc. has assumed the duties as chairman of the board.

James E. Klipp has been named district engineer for Sunray Mid-Continent Oil Company's western Oklahoma district. He will provide technical advice and assistance to the district manager and coordinate the engineering work of the district.

Roger M. Matson has been named chief geologist of The Vickers Petroleum Company, Inc., with headquarters in the company's exploration offices, Denver, Colorado.

Paul M. Crandall has been named vice president of La Gloria Oil and Gas Company and assistant to the senior vice president in charge of the oil division of Texas Eastern Transmission Corporation. Crandall, formerly comptroller of La Gloria, assumes special duties and will assist senior vice president **John F. Lynch** in all phases of oil division activities.

Four personnel changes in its exploration department have been announced by Tennessee Gas and Oil Company. **G. W. McMillan,** former geologist in the Calgary, Alberta district office, has been promoted to district geologist at Calgary. **R. I. Standen,** formerly landman at Calgary, was made district landman. **Ray Blakely,** former geologist in the Denver, Colorado office, was promoted to district geologist there, succeeding **C. S. Algire,** who was transferred to Casper, Wyoming, as district geologist.

W. H. Rosser has been promoted to the newly created position of engineering section chief for Continental Oil Company's interstate gas sales activities. Formerly regional engineer for the company's southern region, he continues to headquarter at Houston. **Martin D. Rowe, Jr.,** southern region staff engineer, has been promoted to regional engineer, succeeding Rosser.

▸ As a result of the organizational changes announced by The Sohio Petroleum Company earlier this year, the company has consolidated its exploration offices in the Gulf Coast. The former Gulf Coast division office at Houston has been eliminated, and district activities consolidated in the new Gulf Coast area exploration office in Houston.

Dwight H. Seely Jr. is in charge of the new Gulf Coast area office as exploration manager. This office is responsible for all exploration activities in South Texas, East Texas, Louisiana, offshore, Mississippi and Alabama.

James H. Morris, formerly Lafayette district exploration superintendent, has been appointed area geologist for Texas and offshore. **Robert J. Field,** formerly staff assistant to the division exploration manager, is now area geologist for South Louisiana.

Reporting to Morris will be **T. C. Danie,** district geologist for South Texas, and **W. L. Rader,** senior geologist for Louisiana, offshore; and Texas areas. Reporting to Field will be **A. J. Napier,** formerly Lafayette district geologist, now district geologist for South Louisiana.

C. E. Storm, formerly assistant division landman, is now area landman in charge of all land activities in the Gulf Coast area. District land offices will be maintained at Lafayette and New Orleans. **Jon Brook** will continue as district landman at Lafayette. **L. L. Fergus** will continue as district landman at New Orleans.

S. A. Hatcher, formerly district geophysicist in New Orleans, now becomes area geophysicist in charge of all geophysical interpretation in the Gulf Coast area. **C. F. Wendenburg** remains in charge of the geophysical ship and field seismic crews.

S. W. Estes, staff assistant, will assist Seely in administrative matters.

▸ **Harold S. Winston** became associated with Neville G. Penrose, Inc. as petroleum engineer in their Midland, Texas office.

▸ Personnel assignments in Gulf Oil Corporation's Denver production district have been completed. Heading the district as manager is **A. M. Bell Jr.** Under him, as managers of the district's various functions, are **L. E. Warren,** exploration; **E. W. Brake,** production; and **W. C. Galloway,** services.

L. E. Warren

Assignments were also announced in Gulf's Midland production district. District manager of Midland is **E. E. Merkt, Jr.**; **H. B. Leeton** is production manager; **J. A. Hord** exploration manager, and **N. B. Martin** manager of services.

On the exploration staff, under Hord at Midland, are **J. A. Norwood,** district exploration geologist, and **R. E. Griffith,** landman.

Manager of the area exploration office in Wichita Falls is **C. E. Davis.**

Production functions, under Leeton, will be handled by **J. L. Coulson,** assistant production manager; **T. W. Kidd,** district engineer; and district production geologist **L. L. Fuller.** Area production managers are **A. J. Evans Jr.** at Crane; **C. H. Jones** at Goldsmith; **C. D. Borland Jr.** at Sand Hills; **V. G. Davis** at Monahans; **C. M. Foster** at Wichita Falls; and **J. F. Eubanks** at Odessa.

Appointments in the services department include **C. E. Fields,** district clerical supervisor; **W. T. Comfort,** purchasing and transportation supervisor, **C. F. Wilson** as general services supervisor, and **R. F. Welter,** district personnel and payroll supervisor.

E. W. Brake

▸ **William R. Horkey** has been promoted to vice president and general counsel of Helmerich & Payne, Inc. He is a member of the executive committee and has been a director of the company since 1958. Also active in management of the company's foreign and domestic subsidiaries, he is an officer and director of each.

W. R. Horkey

W. Speckhard

▸ **Walter H. Speckhard,** area geophysicist for The British-American Oil Producing Company since 1957, has been promoted manager of the company's Southern exploration division with headquarters in Houston, Texas.

Speckhard replaces **F. S. Goerner,** who has resigned his position with B-A to enter private consulting work.

▸ Presentation of the American Petroleum Institute's meritorious safety award was made recently to **Gary Reynolds,** UCLA engineering student, at a ceremony in the Tidewater Building in Los Angeles.

A Tidewater summer employee in the Bakersfield area, the 20 year-old Reynolds was cited for his display of great courage and presence of mind on July 28, 1959, in extinguishing fire on the clothing of a fellow employee and rendering life-saving first aid.

A. M. Bell, Jr.

▸ **Harry Miller,** Oklahoma City, has been promoted to manager of production for Continental Oil Company's central region. He succeeds **R. G. Parker,** who recently was promoted to assistant general manager of the central region. Both men will continue to make their headquarters in Oklahoma City.

▸ **C. W. Smith** has been appointed Mobil Oil Company's comptroller for the Midland exploration and producing division. He replaces **R. C. Drummond,** who was transferred to New York.

▸ **R. L. Boyers,** a petroleum engineer, has joined Ball Associates. **H. S. Mayberry,** exploration geologist, has also associated with the company as business manager and counsel.

▸ California Research Corporation has made the following personnel assignments at the La Habra Laboratory.

Dr. K. H. Hiller has been appointed senior research chemist, basic drilling, in well logging and basic producing research section. **Dr. C. H. G. Oldham** has transferred to La Habra and has been appointed senior research geophysicist in the geophysics research section. **Dr. P. E. Baker** was named senior research physicist, oil recovery processes and **S. H. Yungul** appointed senior research geophysicist in the geophysics research section.

▸ **Dean P. Guerin** and **Robert L. Shick** were elected to the board of directors of Petroleum Technologists. Guerin is vice president of Eppler, Guerin & Turner, Inc., Dallas investment banking firm, and he is a member of the Tekoil Corporation executive committee. Petroleum Technologists is a subsidiary of Tekoil. Shick, of Oklahoma City, is vice president in charge of operations for Tekoil.

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Difference in basic systems of law, language difficulties, and new customs present challenge to landmen in Latin America

Henry L. Brandon
Union Oil Company of California
Guatemala City, Guatemala

THE United States oil industry is conducting exploration operations in more parts of the world today than ever before, including Central and South America. There is a definite place for the landman in those expanding operations and the need for men with his background and training should increase as those operations increase.

Discounting Venezuela, which has been producing oil for years, some interesting developments are taking place in other countries. The oil industry is relatively new in some and not so new in others.

Argentina, who has a long history of opposing outside capital to develop its petroleum reserves, has recently reversed its position and granted several contracts to both American and European companies, to drill, build pipelines and construct refineries.

Under most of the exploration contracts, the producing company is paid in cash for each barrel of oil produced and does not earn an interest in the oil found.

Bolivia is also a relative newcomer in the exploration field, where several major companies are now carrying on extensive operations. Although Colombia and Peru have been producing for years, millions of dollars of outside capital are being spent there.

Paraguay is another scene of operations, even though several dry holes have been drilled there since 1945. Coming into Central America, Guatemala is the latest country to enjoy the benefit of exploration money. At present, 30 companies, many of them majors, are active there.

Drilling is also going on in Costa Rica and several dry holes have been drilled recently in Panama, Nicaragua, Honduras and British Honduras.

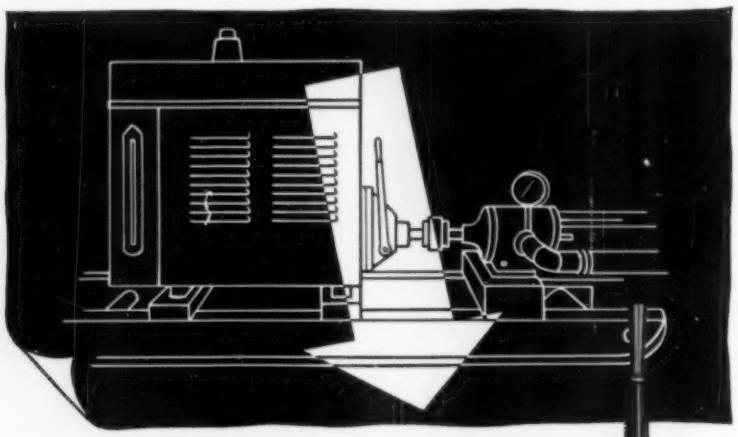
In the Caribbean area, many companies, including several majors, are actively exploring in the Bahama Islands, Jamaica, Haiti, Dominican Republic, Puerto Rico, the Barbados Islands and Cuba.

All of this activity takes millions of dollars and thousands of people to operate. That is where landmen come into the picture.

From the landman's viewpoint, there isn't the same situation in most counties that exists in the United States and Canada. The reason is found in the difference between the basic systems of law.

In many of the English speaking countries, whose law is based on the English Common Law, surface and sub-surface ownership are one.

Two exceptions of course, are public domain in the U. S. and crown lands in Canada. Another exception is Aus-



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Henry L. Brandon, resident manager for Union Oil Company of California in Guatemala, has worked for Union in Havana, Cuba; and Bakersfield and Los Angeles, California. He worked as a landman for The California Company in New Orleans, Louisiana; Bismarck, North Dakota, and Denver, Colorado.

Brandon received a BBS degree from Southern Methodist University in 1948. He received an LLB degree from The School of Law at Vanderbilt University in 1951.

tralia where each state owns the subsurface exclusively.

On the other hand, in most Latin countries, and for that matter in many other parts of the world, the system of law is based on the Napoleanic Code. Under that system surface and subsurface ownership are separate, with the latter remaining in the government.

The right to carry on exploration operations is granted by the government in the form of a concession which does not grant title but merely conveys the right to explore and exploit the sub-surface.

These concessions usually cover very large areas, carry certain work obligations and are limited in their term regardless of whether production is found or not.

In some of the Middle East countries, concessions are granted covering hundreds and even thousands of square miles. This, obviously, eliminates three of the principal functions of the landman, that is, title checking, leasing, and title curative work.

Just as obvious is the smaller number of landmen needed in foreign areas. This is not to say though, that there is no place for them in foreign operations. There are many functions they are prepared to handle because of the very nature of their training.

Landmen, or former landmen, working in foreign countries could be classified roughly into two groups:

1. Management,
2. Land and legal.

Those in management do just what the word implies. They have gotten out of the more or less specialized field of land and legal and are managing their company's operations in one country or, as in some cases, over a larger area. I know of one former landman who is the manager of all his company's foreign operations.

The latter group, land and legal, perform more or less the same function as in the United States.

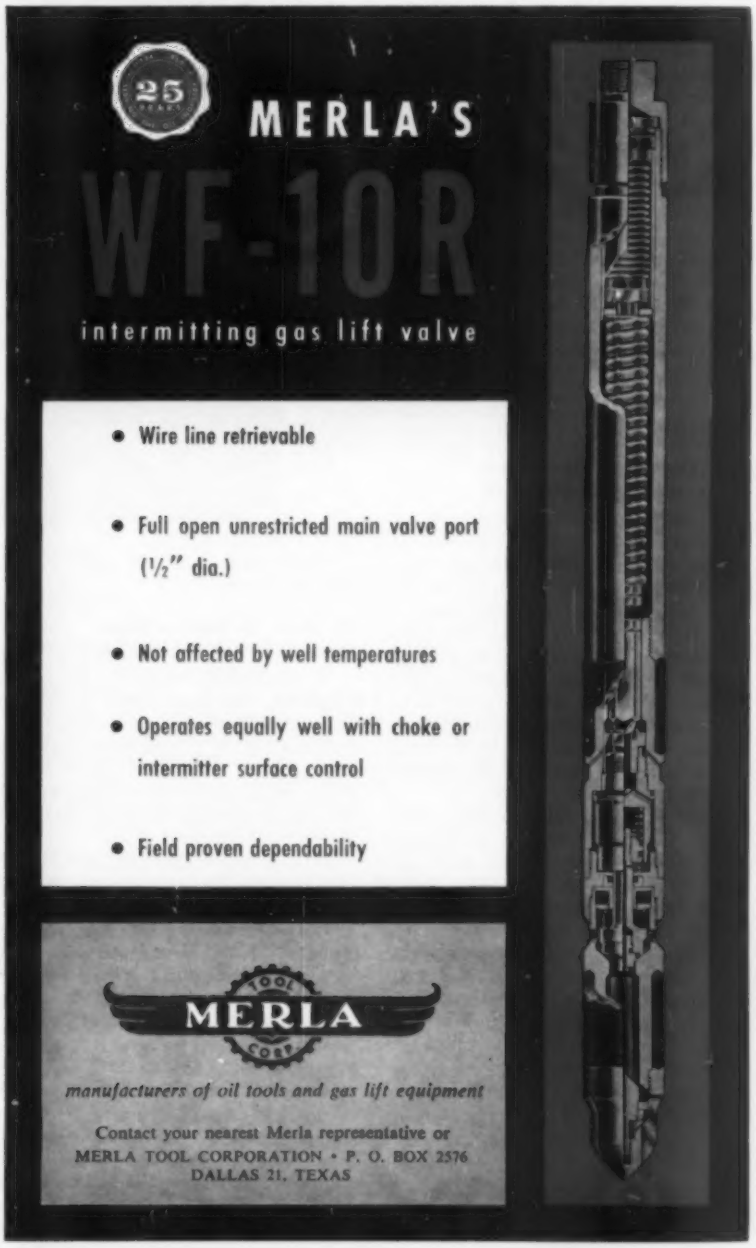
This group itself is sometimes separated in such countries as Venezuela, Trinidad, Colombia, Peru, and to some extent, Cuba. In others such as Guatemala, Costa Rica and Argentina, development is not far enough along to necessitate a separation of the two.

Take Venezuela and Colombia as examples. There are several of the major companies operating there that maintain a separate land department. They maintain titles, purchase rights-of-way, supervise boundary surveys, negotiate farmouts and in some instances, represent their companies in dealings with the government.

In Trinidad, where fee lands are found, leasing is included in these duties. Many of these men are graduate lawyers.

These same companies, in addition to their retained legal counsel, have their own attorneys who handle contracts, joint operating agreements, labor contracts, resident visas and various other legal problems. Like the landmen, they also act as the liaison between their company and many of the government ministries.

On the other hand, in some countries like Guatemala, the land and legal duties are combined and the lawyer-landman finds his hands full. Some of the men in this category spend quite a bit of time investigating petroleum laws and concession activities in countries where active exploration operations are not going on. ★ ★ ★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EXPLORATION ACTIVITIES

CARIBBEAN

First Exploration License Granted on Grand Cayman

An exploration license permitting exploration throughout the British island of Grand Cayman has been granted United States Sulphur Corporation. First test drilling will begin immediately.

Site of initial well will be on the northeast corner of Grand Cayman in a region the islanders have dubbed Hell because of its freakish geological character.

The anomaly is a hole about 1000 ft long by 600 ft wide in which coral rises in forms of peaks ranging in height from 2 to 6 ft. Peaks rise to a sharp, black point that resemble petrified flames.

Test will be the first of four scheduled on Grand Cayman, largest of three islands which form the Cayman group. The main island is about 22 miles long and 9 miles wide. It is located about 180 miles north-northwest of Jamaica and about 150 miles south of Cuba.

U.S. Sulphur plans to drill the four tests as rapidly as possible using an air-drilling rig which will be shipped to the island by LST. Under terms of the license granted the company and E. D. Merren of Georgetown, British West Indies, the company must drill four wells or 10,000 ft of hole within two years.

License covers about 350 sq miles, or the entire island out to the 10-fathom line.

Four tests will be aiming for the Upper Cretaceous formation between 3500 and 5000 ft. Sites of other tests are in south-central portion of the island in an area called Boddentown, east-central interior, and in the Gun Bay area on the far eastern edge of the island.

There is no previous production on the island. In recent years, two shallow tests were drilled. A drilling venture in the Boddentown area was abandoned in 1957 at a total depth of 1317 ft. The second test, which was drilled in the area later, was abandoned at 541 ft when the operator lost the drill bit in a hole.

LOUISIANA

Gas Distillate Discovery Tests at 7,000,000 CFD

A gas distillate discovery on a 2500-acre lease in the Gulf of Mexico off the coast of Louisiana has been completed by Kerr-McGee Oil Industries, Inc. and associated companies.

Well is located in Block 125 East Cameron, about 35 miles from land in 77 ft of water. It was drilled to 12,520 ft and is located on the flank of a piercement salt dome. Well tested gas at rate of 7 million cu ft per day through a 16/64-in. tubing choke with flowing pressure of 4725 lb.

After shutting well, pressure built up to 6200 lb. Well was completed through perforations from 9732 to 9750 ft.

Dual-Zone Discovery Flows in South Pelto

A dual-zone discovery oil well has been completed on Block 19, South Pelto area, in Louisiana offshore waters. Well was a joint venture of Ocean Drilling & Exploration Company, Murphy Corporation, and The Burmah Oil Western Company.

On upper zone, with perforations at 8352 ft to 8358 ft and 8361 to 8367 ft, initial test was at rate of 241 bbl of 33.5 gravity oil per day through a 10/64 in. choke with a gas-oil ratio of 755 to 1 and tubing pressure of 1460 lb. Perforations are from 8443 to 8450 ft.

Well encountered seven oil sands and one gas sand, with a net total of 176 ft in eight zones. Completion was in two deepest zones.

Drilling has begun on another joint well on block.

Wildcat in Pierre Pass Completed as Dual Oiler

A significant discovery in South Louisiana has been made by Union Texas Natural Gas Corporation. Company has made a dual oil completion of a wildcat well, No. 1 State Lease 3426, which is located in Pierre Pass area at north end of Lake Verret in Assumption Parish.

Cabot Carbon Company and J. Ray McDermott, Inc. are co-owners with Union Texas Natural Gas in venture.

On 20-hour test through perforations at 13,222-46 ft, well flowed at rate of 216 bbl of 34 gravity pipeline oil per day through a 9/64 in. choke at 3100 lb per sq in. surface pressure. Second producing interval is from perforations at 13,136 to 13,144 ft and flowed at rate of 193 bbl of 41 gravity pipeline oil per day through a 10/64 in. choke with 3350 psi surface pressure.

Three additional sands were indicated to be productive at depths of 2949, 13,034, and 13,172 ft. All sands are in Miocene formation.

OREGON

Lease Covers 2000 Acres Of Game Commission Lands

A lease covering about 2000 acres of Oregon State Game Commission lands in the Summer Lake game management area of Lake County, Oregon, has been signed by Humble Oil and Refining Company.

Lease carries a directional drilling clause limiting the drilling site to areas adjacent to the game management area. Lease was issued at the regular state-land rental fee of $.25 per acre plus a ⅛ override on royalties.

The land is centrally located with the major 500,000 acre Humble lease block, bringing the company closer to starting drilling operations.

MAURITANIA

Mauritania Grant Covers 13,843 Sq Miles On Coast

A five year exploratory license has been awarded two American oil companies and their French partner by the Republic of Mauritania on West Africa's coast.

The 13,843 sq mile concession is located just south of the Spanish Sahara.

PETROPAR, company controlled by the French Government, will conduct the exploration program. American partners will be Continental Oil Company of Mauritania with 25 percent interest, and Mauritania Cities Service with 24 percent. PETROPAR will have a 51 percent interest.

Slightly less than one-third of concession acreage is offshore in the region between Port Etienne and Cape Timiris, with a narrow strip of marine territory following the shore line another 39 miles south of Cape Timiris.

WYOMING

New Oil Find Indicated In Northeast Powder River

In the northeastern Powder River Basin country of Wyoming, a find is indicated in the True Oil Company 1 Mary-D in Campbell County, Wyoming.

A drillstem test at 7574 to 7589 ft found 610 ft of 21 deg gravity black oil and 90 ft of oil-cut mud. Flowing pressure ranged from 0-350 psi. Final shut-in pressure was 2700 psi. Top of the Minnelusa pay is 7575 ft.

The Minnelusa prospect is eight miles southeast of Mitchell Creek Minnelusa field, a Trigood Oil Co. discovery of six years ago. That well pumped 125 bbl daily. Prong Creek field, a 1959 discovery, lies 12 miles southeast.

Free sets of full-color reproductions of core samples, suitable for office decoration, are available. Request must be made on your company letterhead, and include name of this magazine and date of issue. Address — Core Lab, Box 10241, Dallas 7, Texas.

Underneath Venezuela

"U" Sand, Aguasay Field, Eastern Venezuela: producing depth, 14,027 feet; productive thickness, 180 feet; permeability, less than 0.1 to 250 millidarcys; porosity, 6 to 20%; residual oil, 34.5%; total water, 17.4%.

Today it would be unusual to find an active oil and gas area in a Free World country where basic reservoir information does not carry the Core Lab trademark.

Companies operating both domestically and overseas have long recognized the value of Core Lab's region-to-region standardization of core analysis equipment/procedures/techniques and the presentation of data.

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RUSSIA

Soviets Drill Caucasus, Caspian Sea, and Siberia

Russia is drilling deep holes both onshore and offshore in the Caucasus area.

In the Zyr field on Azerbaijan's Apsheron Peninsula near Baku, drilling has been completed on a 15,929 ft well. Another well in the same field was bottomed at more than 15,800 ft in March.

No production data on the two deep wells was released, but an earlier Zyr field well found oil at about 15,788 ft.

Zyr field is regarded as a testing ground for Russian drilling technology, including combined rotary and turbine drilling, diamond bits, electric turbodrills, and weighted turbodrills. Planning work has been finished on a 22,965 ft well in the Zyr district.

In the Caspian Sea east of Baku, construction has been started on a steel island, from which a 14,764 ft exploratory well is planned. Six 90 ton steel supports for the island have already been sunk in 95 ft of water.

Russia has made a gas discovery at the extreme western tip of the Crimea at a depth of only 1600 ft. Test flow was about 2,800,000 cu ft daily.

The Soviets consider the well to be of great interest because Crimean gas previously had been found only on the Kerch Peninsula — the Crimea's eastern end. Latest discovery is located southwest of Chernomorskoe, near the village of Olenevka.

Russia claims to have made an important oil strike in western Siberia, where there has been extensive exploration to find commercial reserves.

Discovery well, located on the bank of the Konda River in Tyumen Province, flowed up to 220 bbl daily in test. The oil, found at about 4700 ft, is said to contain up to 50 percent light fractions.

Western Siberian well is in a roadless, floodland area 217 miles north of the city of Tyumen and 137 miles northeast of Serov. It is over 300 miles northeast of the nearest Second Baku oil fields near Perm, west of the Ural Mountains.

VENEZUELA

1,000,000 Acres Dropped

Oil companies operating in Venezuela have dropped over one million acres of leases this year, continuing a trend.

Cia Shell de Venezuela has relinquished 404,976 acres. In Zulia State 10,102 acres were dropped northwest of the Mara field, and 64,664 acres were relinquished in Maturin District of Monagas.

Remaining 281,834 acres dropped by Shell are located in Anzoategui and Guarico. Biggest concentration of these rights covered 108,463 acres in Cagigal district of Anzoategui.

Caracas Petroleum dropped 24,273 acres in Guarico, and Esperanzo Petroleum renounced 73,697 acres in the Cagigal area.

In the Jobo area of southern Monagas, Pan Venezuela released 11,113 acres and in southern Apure they released three exploration parcels covering 74,100 acres.

In the Buchivicoa area of Falcon, Texaco gave up 182,407 acres. Creole let concessions drop that covered 252,893 acres in Guarico. Acreage dropped by Venezuela Atlantic was 89,241 acres in Anzoategui and Guarico, 53,204 acres in Barinas Block 27, and two exploration blocks in Apure covering 49,400 acres.

INDIANA

Wildcat Well Completing

H. C. Farmer is completing the 1 Eva Varner Gentry wildcat in Spencer County, southwest Indiana. Wildcat well is at SW SE NE 33-4s-fw, 1 mile east of Lincoln City. Well made 12 bbl of oil per day from Aux Vases at 1040 to 1051 ft. Location is 1¼ miles from previous production.

Continued on Page B-80

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PEPA Elects New Officers and Directors

During its annual meeting June 5-7 at Jackson, Mississippi, the Petroleum Electric Power Association elected the following directors and new officers: (seated, l to r) H. R. Winters, Oklahoma Gas and Electric Co.; secretary-treasurer and director, Kirby Dawkins, West Texas Utilities Co.; president, W. M. Larkin, Gulf States Utilities Co.; vice president, B. F. Thompson, Public Service Company of Oklahoma; and F. R. Woerner, Texas Electric Service Co.; (standing l to r) H. P. Lindsey, Arkansas Power & Light Co.; Paul Atwell, Mississippi Power & Light Co.; D. S. Coffman, Texas Power & Light Co.; Jas. E. Moody, Southwestern Electric Power Co.; Julian B. Taylor, Jr., Houston Lighting & Power Co.; Langston Ashford, Central Power & Light Co.; and J. E. Reed, Jr., New Mexico Electric Service Corp.

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TEXAS

Deep Test Finds Oil In 5100 Ft Frio Zone

In Victoria County, South Texas, a deep test off the northeast side of the East Telferner field in Victoria County found oil in the 5100 ft Frio zone.

Discovery well is the Catahoula Oil & Gas Company I Owen Kolle. It is in the Thomas Burnham Survey, A-132, five miles southeast of Telferner. The well flowed 52 bbl of oil per day on 10/64 in. choke from 5100 ft Frio pay. Established production in the area is also in Frio at 5090 to 5093 ft.

Logs Made Available On Helium Gas Wells

Responding to requests from private industry, U.S. Bureau of Mines has made public electrical and radiation logs of the government's helium-bearing natural gas wells in Texas and New Mexico.

Well logs used to guide Bureau operations in the Cliffside, Texas, and Rattlesnake, New Mexico, gas fields are on open file and can be seen during regular office hours at the Office of the Assistant Director, Helium, Room 4627, Interior Building, Washington, D. C., and the Office of the General Manager, Helium Operations, Room 514, Barfield Building, Amarillo, Texas.

PORTUGUESE GUINEA

Drilling Contract Awarded To Commence Exploration

Drilling and Exploration Company, Inc. has been awarded a drilling contract by Esso Exploration Guine', Inc., a subsidiary of Standard Oil of New Jersey, under terms of which Drilexco will furnish supervision and technical skill for the drilling of several exploratory wells in Portuguese Guinea, West Africa.

Equipment for the drilling program will be shipped from Malta and will arrive at the port of Bissau on Africa's west coast about October 1.

This program marks the commencement of oil and gas exploration activity in Portuguese Guinea.

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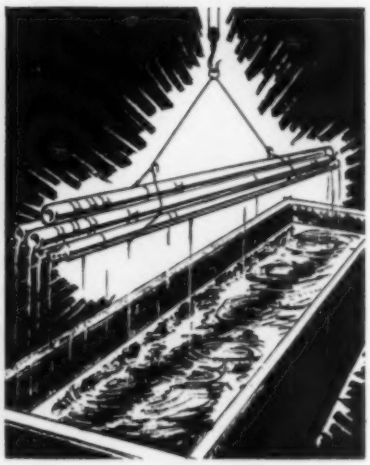

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SUPPLIERS' PARADE

Pan Geo Atlas Corporation of Houston has established a new French subsidiary company, PGAC Sahara, S.R.L., with headquarters at 65 Avenue des Champs Elysees, Paris. Subsidiary's field operations are now well under way in the Algerian oil fields.

All types of oil well logging, perforating, and other wireline completion services are being performed in the Algerian Sahara area of Edjeleh, south of Tunisia and close to the Libyan border.

M. DeMalleray, well known in the French oil industry, has been appointed general manager of PGAC Sahara, S.R.L. Field operations are being directed from Maison Rouge, OCRS, Africa.

Robert Ross has been appointed as operations manager for PGAC's Sahara field activities. He was promoted from former duty at PGAC's district in Lafayette, Louisiana.

John Robinson, now serving as assistant operations manager of PGAC's Algerian activities, was transferred from the company's station at Odessa, Texas.

L. Lee Norman, Jr., assistant manager of PGAC's electrical logging department at Houston, has been assigned temporarily to the company's Saharan operations and is in charge of all field activities.

Two complete field parties are already on duty in the Edjeleh oil fields. Upon the completion and operation of the 500-mile pipeline now under construction from the Tiguentourine-Edjeleh-Zarzaitine oil fields through Tunisia to the port of Gabes, on the Mediterranean Sea, stepped-up drilling activities will probably require additional equipment and men.

Houston Oil Field Material Company. J. T. Kenneally, who has been serving as executive vice president, has been named president of HOMCO. Frederick W. Richmond of New York was named chairman of the executive committee. Other members of the company's board who were re-elected are Z. C. Ambrose, D. J. Hayden, Eliot Janeway, Clarke Simonds, and A. W. Waddill. C. L. Roach, vice president in charge of domestic operations, was also elected to the board.

J. T. Kenneally

Alten Foundry and Machine Works. Noel D. Morris has been named manager of the new well drilling machinery division at Alten Foundry and Machine Works. This marks Alten's entry into the well drilling machinery field and follows their securing the design, engineering and manufacturing patents of the Loomis Machine Company. They are now manufacturing and marketing new models of the Loomis rig in two sizes, 24 and 32.

Known as the Alten-Loomis Super Clippers, these rigs can now be purchased through an increasing number of Alten dealers.

Parkersburg-Aetna Corporation. Craig M. Rowley was elected president of Parkersburg-Aetna following the promotion of Bernard P. McDonough to the position of chairman of the board of directors.

PRODUCING SLIM-HOLE?

RUN A

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With domestic allowables and markets as they are, the trend is toward slim-holes . . . for completing in new areas . . . for marginal wells . . . and for fully exploiting pays that are on the verge of depletion. Little Squirt Pumps have been carefully designed to afford all of the operating advantages desired in small-volume production . . . with the stamina and dependability of regular-sized pumps. Whether you complete single- or multiple-string, there's a Little Squirt available . . . four in rod pump sizes, including hollow rod types, and five tubing pump sizes, with metal or cup plungers.

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FORT WORTH

Byron Jackson Division. Harold B. Bruwelheide has been named controller and treasurer of the Byron Jackson division of Borg-Warner Corporation. He replaces Franklin Sloff, who is being transferred to a new position at Borg-Warner's Chicago headquarters.

Three oil tool sales personnel have been promoted in the Mid-Continent region. John P. Kirby has been appointed product sales manager for BJ tubing swabs. F. J. Gray moves from Odessa, Texas to become city sales representative for the Dallas-Fort Worth area. V. J. Carter has been named manager of the district immediately surrounding Odessa, Texas, where he will continue to maintain headquarters.

Mission Manufacturing Company. Edgar Lea Carter has joined the firm as sales representative for the Houma, Louisiana, area.

Core Laboratories, Inc. has announced the recent promotion and transfer of Frank O. Reudelhuber from Dallas, Texas, to Paris, France, where he is now serving as manager of the firm's newly-formed subsidiary, Francecorelab.

F. O. Reudelhuber

C. D. Crickmer

Baash-Ross Division of Joy Manufacturing Company. Charles D. Crickmer has been promoted to position of chief engineer. Previously he was assistant chief engineer in charge of engineering activities at the Baash-Ross plant in Houston.

George E. Failing Company. V. C. Mickle has joined the sales staff of George E. Failing.

Western Supply Company has appointed Jack R. Norris district manager at Longview, Texas. His duties will include sales promotion and overall management. He will cover a territory including East and North Texas, and Southern Oklahoma.

J. R. Norris

James B. Hill

Magnet Cove Barium Corporation has appointed James B. Hill president of Pacific Mud Company, California affiliate of Magcobar. Dan Mathews was promoted from sales and service engineer, drilling mud department, to the newly created position of assistant advertising manager. Jep Woody, sales representative in West Texas region, drilling mud department, has been promoted to sales coordinator of the region. Harry Allred, sales and service engineer at Mineola, Texas, Southeastern region, will succeed Woody as sales representative in the West Texas region.

The National Supply Company. Russell J. Wisecup, supervisor of rotary equipment sales for The National Supply Company in Venezuela, has been transferred to the Export Division headquarters in New York City as division engineer, drilling. Galen L. Lindner will continue as division engineer, production.

Jones & Laughlin Supply Division, a division of Jones & Laughlin Steel Corporation, has changed their Denver, Colorado, office address to 360 Denver Club Building. The Denver office, headquarters for J&L's Rocky Mountain Region, is under the direction of D. H. "Kit" Carson, regional manager.

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"SLIM HOLE" SAND PUMP

Miller 2" OD Sand Pumps for 2⅞" OD "Slim Hole" completions are now available. The 2" OD Sand Pump, with accurately machined lug-type bottoms, is designed exactly the same as larger Miller Sand Pumps.

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Composite Catalog, Page 3688

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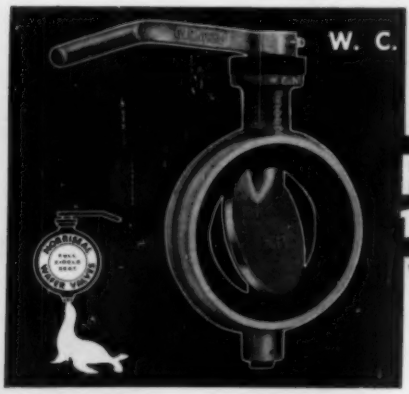

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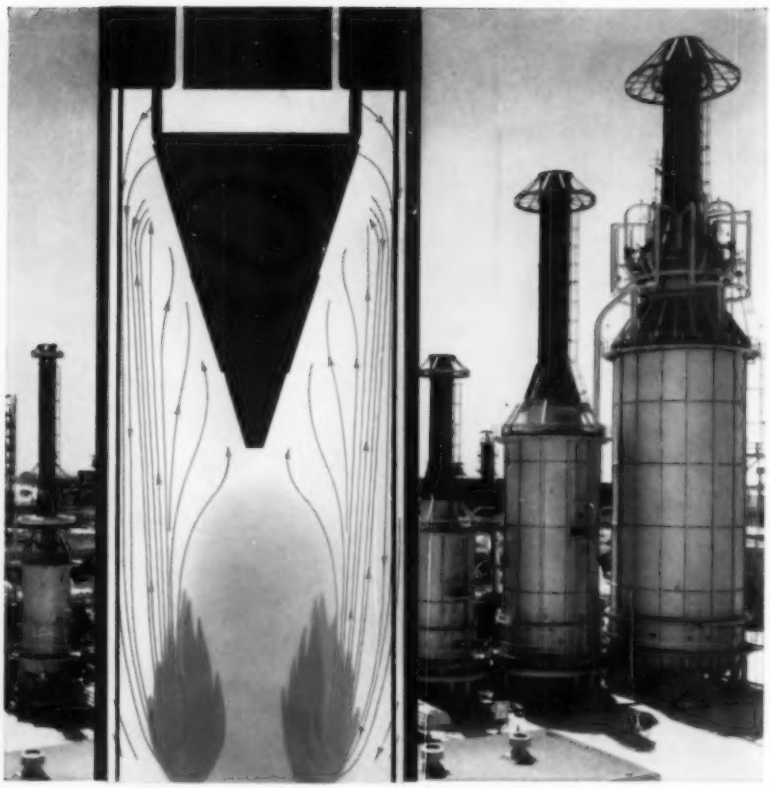

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How to handle TEL susceptibility in linear programming of gasoline blending studies

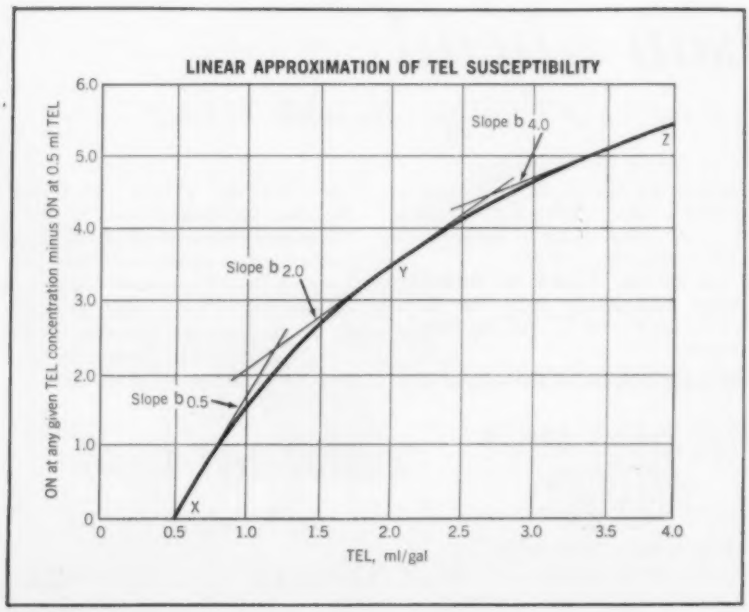
By Dr. W. C. Healy, Jr., Supervisor of the Computation and Economics Section,
Refinery Technology Division, Ethyl Research Laboratories

In past years, gasoline blending was comparatively simple. An engineer could establish optimum blends for two grades of gasoline by using a slide rule and a TEL response chart.

Today gasoline blending and establishing maximum antiknock effectiveness are much more complex. Many components are used to make numerous grades of gasoline. Often, market conditions divert some gasoline component to another product. All this presents the refiner with a giant-sized problem of blending for maximum profit.

The magnitude of the problem has forced the refiner to electronic computer solutions, using such techniques as linear programming.

Because TEL susceptibility is a non-linear function, it presents a special problem for computer studies when linear programming is used. Many suggestions have been made for handling the TEL function, and one of the simplest recorded to date is outlined here.



The Ethyl method of handling the TEL function is similar to others in that a target TEL susceptibility curve is approximated by straight-line segments having fixed slopes. However, it is easier to use because—

A. No extra variables are introduced.

B. No extra upper-bounding conditions are required.

C. Set-up time is reduced.

Calculating TEL linear approximations is not difficult when final blend TEL susceptibility* is known. It becomes difficult when susceptibility is to be determined by computer. Calculations must employ approximated susceptibility values while retaining accuracy for reasonable deviations.

*TEL susceptibility is here defined as the difference between octane numbers at 4.0 ml. TEL/gallon and at 0.5 ml. TEL/gallon.

Here's How Ethyl's Method Works

For example, in the figure, three line segments are used to approximate the curve. The procedure is as follows:

A. Estimate a blend TEL susceptibility curve and then plot on rectangular coordinate paper.

B. Draw three approximating lines so that one line passes through point X (0.5, ON at 0.5), the second line passes through Y (2.0, ON at 2.0), and the third line passes through Z (4.0, ON at 4.0).

C. Determine the slopes of these approximating lines, $b_{0.5}$, $b_{2.0}$, and $b_{4.0}$, as shown on the accompanying chart.

Then the following inequalities are required; they state that the ml. TEL per gallon shall be no less than that required on any line segment, and no greater than 4.0.

1. $\text{TEL} \geq \frac{\text{ON (specification)} - (\text{ON at } 0.5)}{b_{0.5}} + 0.5$

2. $\text{TEL} \geq \frac{\text{ON (specification)} - (\text{ON at } 2.0)}{b_{2.0}} + 2.0$

3. $\text{TEL} \geq \frac{\text{ON (specification)} - (\text{ON at } 4.0)}{b_{4.0}} + 4.0$

4. $\text{TEL} \leq 4.0$

Let

$X_1, X_2 \cdots X_n$ = Barrels of each component in the blend.

ON_i at 0.5 = Corresponding octane blending values at 0.5 ml. TEL/gal.

ON_i at 2.0 = Corresponding octane blending values at 2.0 ml. TEL/gal.

ON_i at 4.0 = Corresponding octane blending values at 4.0 ml. TEL/gal.

And $Y = (\text{TEL})(\Sigma X_i)$

Ther substitute in 1, 2 and 3 above

$$\text{ON at } 0.5 = \frac{\Sigma X_i (ON_i \text{ at } 0.5)}{\Sigma X_i}$$

$$\text{ON at } 2.0 = \frac{\Sigma X_i (ON_i \text{ at } 2.0)}{\Sigma X_i}$$

$$\text{ON at } 4.0 = \frac{\Sigma X_i (ON_i \text{ at } 4.0)}{\Sigma X_i}$$

and multiply 4 by ΣX_i

These inequalities then reduce to the required linear expressions:

5. $\Sigma X_i (\text{ON spec} - ON_i \text{ at } 0.5 + 0.5\, b_{0.5}) - b_{0.5} Y \leq 0$

6. $\Sigma X_i (\text{ON spec} - ON_i \text{ at } 2.0 + 2.0\, b_{2.0}) - b_{2.0} Y \leq 0$

7. $\Sigma X_i (\text{ON spec} - ON_i \text{ at } 4.0 + 4.0\, b_{4.0}) - b_{4.0} Y \leq 0$

8. $Y - 4.0 \Sigma X_i \leq 0$

Under certain conditions the number of inequalities may be reduced to three or less.

Susceptibility Changes Are Compensated

Error-compensation is a built-in feature with this method since, when blend susceptibility varies (higher or lower) from the estimated value, the line segments adjust themselves to the proper portion of the new curve.

For greater accuracy, more than three line segments may be used to approximate the susceptibility curve. This requires additional analogous inequalities, but no additional variables.

Each additional octane specification calls for an estimated susceptibility curve and the statement of inequalities as shown above.

Checking the program before the computer run.

How Ethyl Research can help you

Ethyl Research has several years' experience with linear programming as it applies to gasoline blending. This background has been especially valuable for customer service work.

The new method of handling tetraethyllead susceptibility is one example of the professional assistance available to the refiner from Ethyl.

In addition, the Computation and Economics Section in our Refinery Technology Division will be glad to share its experience in computation techniques with your people.

For further information, ask your Ethyl Representative for a copy of "Two Approximation Problems in Linear Programming of Gasoline Blending" presented at the Computer Conference of the WPRA in Tulsa, December 1, 1959. He'll also be glad to arrange an appointment for you with one of our Mathematical Analysts.

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Baton Rouge, Louisiana

A superfuel . . . liquid hydrogen

PAUL D. FULLER
Process & Project Engineer

IRVING A. CORNWELL
Operations Project Manager

Stearns-Roger Mfg. Co.
Denver, Colorado

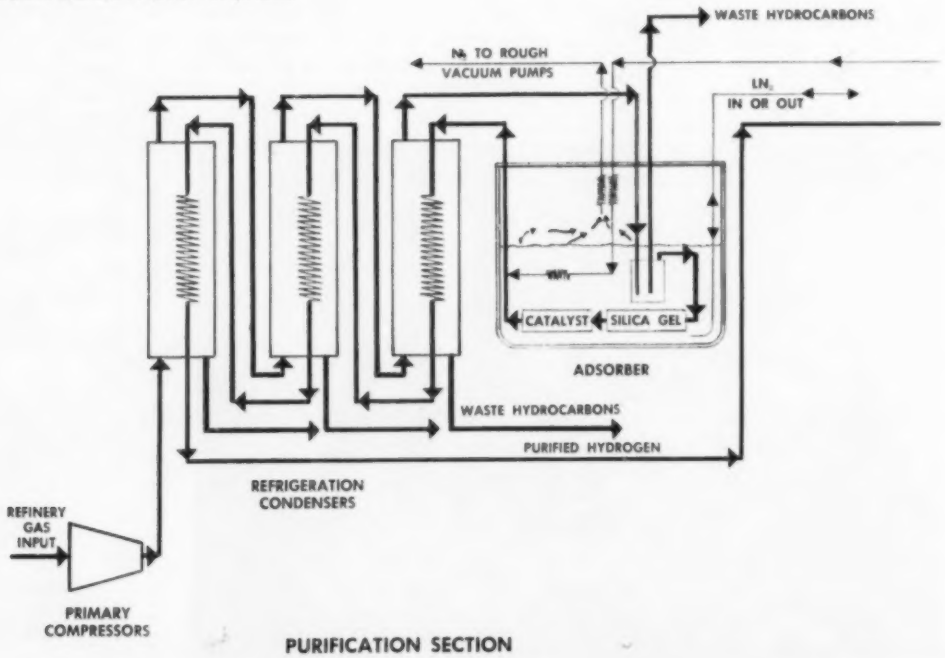
FOR A NUMBER OF YEARS the manufacture of liquid hydrogen for use as a rocket fuel has been classified for security reasons. Now most of the details of the first plants have been released, including data on the pioneer production unit designed, built, and operated by The Stearns-Roger Mfg. Co. at Bakersfield, California. The plant is Air Force-owned and has been operated by Stearns-Roger since November of 1957. A. D. Little, Inc., served as process consultants during design and construction of the facility.

The average monthly production rate is now considerably above the original design rate because of the large demand for liquid hydrogen in the area. A number of months the rate of production has exceeded 130 percent of rated capacity. This has been accomplished by improved operating techniques and onstream production rates of 95 percent.

Of all the chemical fuels, hydrogen has by far the highest heating value on a weight basis. It therefore is of great interest as a long range rocket fuel. Its use, however, involves the new field of cyrogenic engineering, as hydrogen boils at 20.4 K (–423 F). Hydrogen is being used with the best presently available oxidizer — liquid oxygen — which also boils at the relatively low temperature of 90.1 K (–298 F). These two facts go far to explain the current intense interest in cryogenics.

Stearns-Roger's interest in cryogenics began in 1942, when the Exell helium recovery unit was built for the Bureau of Mines near Amarillo, Texas. In 1952 a liquid hydrogen production facility was constructed by Stearns-Roger for the U. S. Atomic Energy Commission. This plant, located at Boulder, Colorado, is operated by the National Bureau of Standards. At that time this small plant was the largest producer in

FIG. 1. Simplified flow diagram, hydrogen liquefaction process.



. . . from refinery off-gas

the Free World. The Bakersfield plant then represented the next phase of development of tonnage hydrogen plants.

Three sources of hydrogen were considered – electrolytic, manufactured (Girdler processes, etc.), and petroleum refinery off-gas. The platformer off-gas was the most attractive because of its availability and low cost (4 to 8 cents per 100 cu ft). Electrolytic was too expensive ($1.00 to $1.50 per 100 cu ft in large quantities) and not available in large enough quantities. The plant was to operate only one year so it was not considered logical to put in a gas generator with so much refinery off-gas available within the general area assigned by the Air Force. Therefore, the refinery off-gas was selected.

The Bakersfield location was selected primarily for its central location to the intended users and to take advantage of by-product hydrogen from the nearby petroleum refineries. The source, a catalytic reformer unit, produces 75 to 90 percent hydrogen, the remainder being mostly low-boiling hydrocarbons.

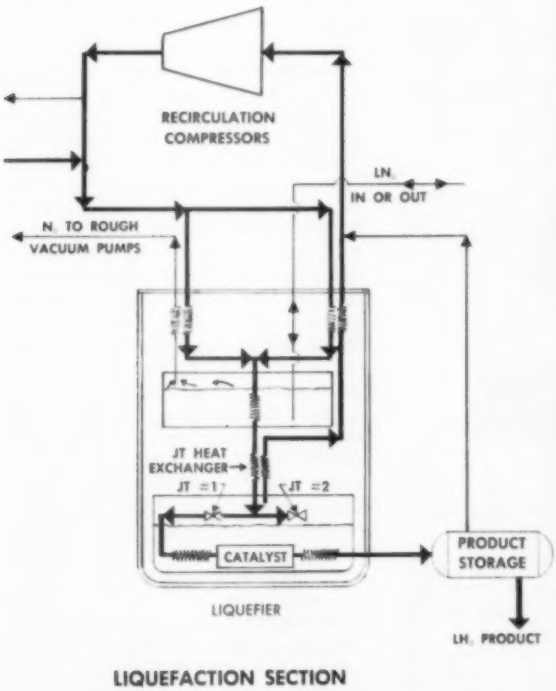
Ortho-Para Conversion

A major complication in hydrogen liquefaction and storage arises from the fact that it exists in two forms, ortho and para. The only actual difference is the orientation of electron spin which in turn accounts for a difference in energy level. At ambient temperature, the ortho-para equilibrium is about 25 percent para, but at 20.4 K (–423 F), this increases to 99+ percent para. Because the heat of conversion from ortho to para (per pound converted) is strongly exothermic — about one and one-half times the heat of vaporization — storage of unconverted liquid results in prohibitively large amounts of vaporization. The problem was solved when the National Bureau of Standards discovered a satisfactory catalyst permitting rapid conversion to the more stable para form. Thus the slower, uncatalyzed conversion in the storage Dewar with its accompanying loss due to evaporization is avoided. The Bakersfield facility makes use of the latest National Bureau of Standard's findings in that hydrous-ferric-oxide was used in place of the older catalysts like chromic oxide.

Referring to the flowsheet, Fig. 1, the plant consists of two sections — the purification section, which removes hydrocarbon and other impurities by cryogenic techniques; and the liquefaction section, which cools and condenses the purified hydrogen.

Purification

The purification section is the most interesting in that it was rather new and novel at the time the plant was designed and constructed.



LIQUEFACTION SECTION

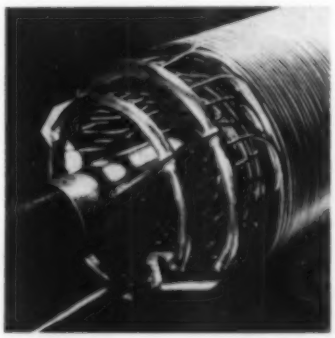


FIG. 2. Giauque-Hampson type heat exchanger. This one is a hydrogen to nitrogen exchanger from the liquefiers. High pressure H_2 gas inside tubing, low pressure (10 to 15 cm Hg absolute) N_2 gas on the outside.

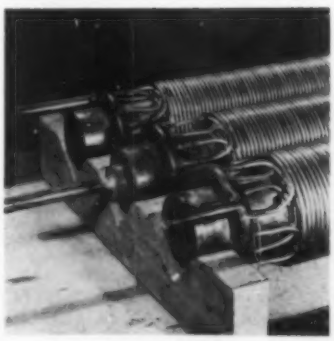


FIG. 3. Giauque-Hampson type heat exchangers for refrigeration condensers. Two units on the outside show bottom ends, whereas the middle one shows the the top end of a typical exchanger.

Any hydrogen liquefier requires a very pure hydrogen feed gas, because all impurities in the gas (except helium) solidify in the heat exchangers of the liquefier and eventually plug them. A high-pressure Joule-Thomson liquefier, such as was used at Bakersfield, is especially sensitive to plugging because of the small size of heat-exchanger passages through the 3/16-in. OD by .035-in. wall copper tubing. See Fig. 2 for typical Giauque-Hampson liquefier heat exchanger.

If any extended running is expected for the liquefier, impurity levels in the hydrogen feed gas should be of the order of 10 parts per million. About the only way to remove impurities to such a level is by adsorption on silica-gel molecular sieve, or activated charcoal at liquid-nitrogen temperatures.

As mentioned above, many possible sources of refinery waste gas are available. This hydrogen rich gas contains impurities ranging from 5 to 25 percent of assorted hydrocarbons depending on the time elapsed since catalyst bed regeneration. At many refineries this hydrogen is considered as a waste gas and flared except when it can be used as fuel.

Typical gas analyses indicating impurity range of the reformer off-gas supplied to the Bakersfield facility are:

	3 April 1959	28 October 59
Hydrogen	81.9	93.5
Methane	7.5	1.5
Ethane	4.6	1.6
Propane	3.7	1.7
Isobutane	0.8	0.5
N-Butane	0.8	0.4
Butenes	0.1	0.1
Isopentane	0.4	0.4
N-Pentane	0.0	0.1
Pentenes	0.1	0.1
Hexanes Plus	0.1	0.1
Total Mole %	100.0	100.0

It is interesting that when this gas is cooled to 78 K, all of the impurities condense out during the cooling except for a small amount of methane. This suggests the method of purification. If all these liquid hydrocarbons can be conveniently drained out of the heat exchanger, purification of this otherwise very poor gas need not involve any more equipment than would be required for the purest available gas; that is, a simple heat exchanger and an 80 K adsorbent bed.

Trouble might arise if significant amounts of these impurities were to condense out as solids. Thus, for instance, carbon dioxide in large amounts would be a real problem and would have to be removed by other means. Most of the impurity hydrocarbons however have triple points at fairly low vapor pressure; thus, virtually no solids are formed in condensation. (An exception to this is methane.)

Fortunately, however, it can be planned to remove the methane, which would condense out as solid in the adsorbent bed, as methane is the last impurity to thermally condense out with lowered temperature and provision may therefore be made to remove it in an adsorbent bed under conditions which do not cause plugging.

One further precaution must be taken to prevent the condensed liquid impurities from flowing into a colder region, where they would solidify and plug the heat exchanger. This is accomplished by mounting the heat exchangers vertically and causing the impure gas to flow upward as it is cooled in the heat exchanger. The impurities then flow back downward by gravity to warmer regions after they condense. There is, therefore, no possibility of their freezing to solids.

After condensation, the liquid impurities should not be warmed very much before they are removed or they will re-evaporate. To accomplish this, the heat exchanger was separated into three vertically mounted sections, as shown on flowsheet, with impurity removal taps at the bottom of each section. Liquid impurities which would be removed from the first tap, if at room temperature, would be pentane, butane, and water. The second tap would drain off principally propane and ethane, and and the last methane. The heat exchangers used were of the Giauque-Hampson type, 3/16-in. by .035-in. wall copper tube, shown in Fig. 3. The impure gas flows on the outside of the tubes, the purified gas back through the inside of the tubes. Final condensation separation is made in the liquid nitrogen bath of the adsorber just before the gas enters the silica-gel bed. This heat exchanger removes methane that is not condensed in the coldest refrigeration condenser. Part of the methane is taken out as rime and the condensed portion is drained every 15 minutes.

The condensation of impurities in the heat exchangers flows downward due to gravity, and partial re-evaporation has an interesting effect on the temperature pattern in and performance of the heat exchangers. The result is automatic adjustment of the temperature at the bottom of the second and third heat exchangers to a temperature which is convenient for the removal of impurities taken out there. A change in the impurities involved, so that total impurity vapor pressure relations are changed, or a change in the amounts involved, will be adjusted for by the heat exchanger. A small amount of gas is taken from the discharge side of the recirculation compressors, and fed back into the purified hydrogen stream in the adsorber, to balance enthalpy changes through the refrigeration condensers. The use of the system without impurities gives decidedly different temperature patterns in the heat exchangers.

The liquid impurities are drained off every 15 minutes and exhausted in a nearby field for evaporation. No attempt is made to recover either the gas or the refrigeration in the cold waste liquids. A considerable saving in purifier refrigeration requirements could be made by heat exchange with the exhausting gases, with relatively small modifications in the system. However, since the purifier refrigeration requirements are small relative to the liquefiers, the additional complexity was not

ABOUT THE AUTHORS

PAUL D. FULLER is process and project engineer in the special products division of Stearns-Roger Mfg. Co., Denver. He was instrumental in project engineering of the Air Force's Bakersfield, California, liquid hydrogen plant and also the initial process engineering of the the facility. He served as cryogenics consultant during preparation of plans and specifications for the earlier Atlas ICBM launch complexes and was project manager on a 100,000 std cu ft per day helium reclamation system at an Air Force test facility. He holds a BS in mechanical engineering from the University of Colorado.

IRVING A. CORNWELL, also with Stearns-Roger, has served as operations project manager of the Bakersfield facility since 1958. He has worked as contract administrator on Air Force, Navy, and Atomic Energy Commission projects. He formerly was a contract specialist for the Air Force and was responsible for negotiating, writing, and administering research and development contracts. He has a BS degree from the University of Minnesota.

considered worthwhile for a plant of this size and that had an expected life duration of only one year in 1956.

The removal of methane down to trace amounts (only 10 ppm or less) was quite a problem. Liquid-nitrogen temperature (77.3 K) is well below the triple point for methane (91.6 K), and methane has a relatively high vapor pressure at its triple point. Thus, significant quantities of solid methane can form in connecting tubes and plug the silica-gel beds. Trouble was had with this during plant start-up and a study to find the best geometry which would collect large amounts of solid methane without plugging would be very worthwhile.

The liquid nitrogen bath in the adsorber section also provides a convenient location for partial conversion of the hydrogen. The catalyst bed in the adsorber raises the para content from approximately 25 to 50 percent. This 25 percent raise is quite significant when considering the ultimate yield of the liquefier. This method allows for the heat of conversion to consume liquid nitrogen rather than additional refrigeration in the liquefier at –423 F where refrigeration is very expensive.

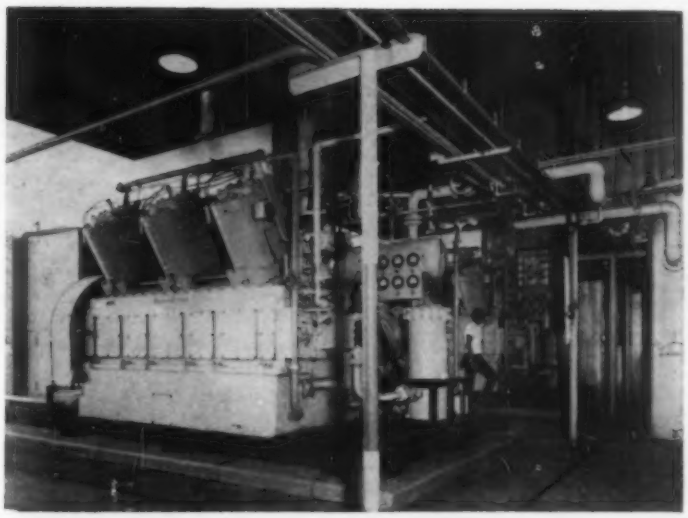


FIG. 4. Two of the 330 hp recirculation compressors.

Liquefaction

The liquefaction cycle was patterned after the National Bureau of Standards plant, in which efficiency was sacrificed to achieve the high reliability inherent in the simple Joule-Thomson (JT) expansion valve. About 20 percent of the total stream is liquefied as product for transfer to the storage Dewar and the rest is recycled to the compressors, furnishing cooling for the incoming stream. As shown in the flowsheet, a dual expansion valve system is used, in which the 20 percent product stream is flashed from 1600 psig to approximately 25 psig through the JT Valve No. 1 in a closed system surrounded by condensate obtained from the 80 percent stream flashed through JT Valve No. 2 to substantially 5 psig.

The dual expansion valve system was chosen for certain advantages and to circumvent the problems created by the "batch" transfer method or the need for a liquid hydrogen pump. "Batch" transfer is questionable for a plant of this capacity and also complicates the design of the critical JT heat exchanger because the ortho-para content of the two gas streams would be different.

Pumps for liquid hydrogen are available but elimination of mechanical equipment operating at –423 F is usually advisable. The dual valve system makes high pressure gas available such that the pumps can be eliminated and allows the final product to be subcooled in the liquefier before transfer. In this way provision is made for part of the heat which will be transferred to the liquid during transfer and in the storage Dewar. The liquid hydrogen boiled-off to provide this refrigeration is in the liquefier where the refrigeration in the gas can be used. The liquid hydrogen bath maintained by the recycle stream removes the energy released in the second catalytic converter and as mentioned above condenses and subcools the 25 psig product before being transferred to storage Dewars. The converter raises the para content from 50 to 95 percent or higher, as demanded by Air Force specifications.

Physical Discussion

Transfer lines for the liquid nitrogen and hydrogen were constructed of the high vacuum type. This means that the liquid transfer line is spaced inside of a larger outer line, and the annular space formed is maintained at a maximum pressure of 1×10^{-5} mm Hg absolute. At this pressure the only appreciable heat transfer to the liquid is by radiation. The inner line of the hydrogen transfer line was wrapped with a number of layers of spaced aluminum foil to add radiation shields and thereby reduce heat gain to the liquid hydrogen.

The inner line was fabricated with seamless stainless steel pipe and forged socket-weld fittings. All joints were heliarced to insure strength and leak tight joints. The configuration of the line (approximately 150 ft long) was made so that the inner line was one solid piece without bellows. All contraction of the line was handled with bellows in the outer line and the "dog-legs" provided by selective location of the liquefiers in relation to the liquid hydrogen storage Dewar. Snubbers on the bellows, slide plates, rollers, spring loaded vertical supports, etc. were provided for movement of the line during cool-down and warm-up. The liquid nitrogen transfer line was constructed much the same except that copper pipe and bronze fittings were used throughout as they were on the outer portion of the liquid hydrogen line. Connectors on the hydrogen lines were of the "bayonet" type, whereas the nitrogen lines had direct seal between the liquid line and the outer vacuum line.

Adequate equipment for liquid hydrogen service was very hard to obtain in 1956 and 1957, therefore, some of the equipment was custom designed or reworked existing hardware. A prime example of this was valves to be packaged into the high vacuum transfer lines discussed above. Success was had by improvising two quite different existing valves. One method was to seal weld valves of the split body bellows sealed type and then operate the valve through an O-ring sealed stem extension protruding through the outer vacuum shell. This method allows for operation of the valve but is designed so the stem can be disengaged in the vacuum space, thereby eliminating any direct heat leak. This is known as the "broken-stem" type. The other method was to extend the stem (commonly done to make cryogenic valves that are left uninsulated or insulated with a solid insulation) of an ordinary solid body globe configuration valve. The composition seat material of the plug was replaced with Teflon and the stem and bonnet extended with long thin sections such that the stem packing could be extended out through the outer vacuum shell. This extension has to be designed long enough to minimize the heat leak into the liquid. This method has an advantage in that the bonnet seal can be outside of the vacuum space and

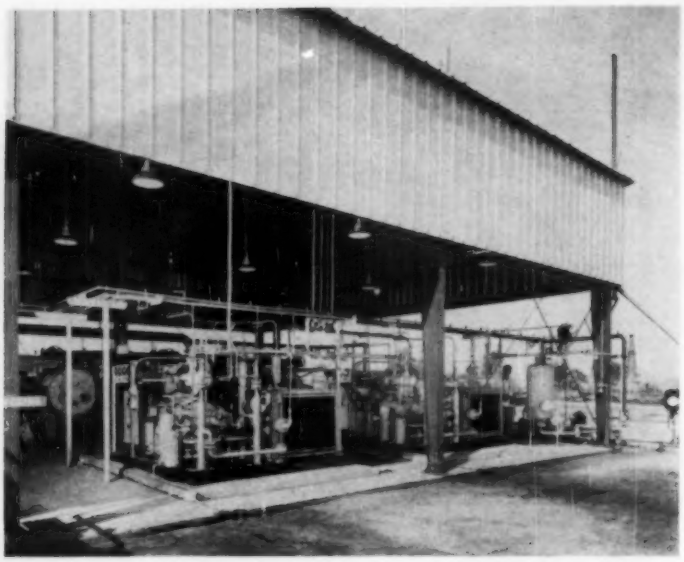


FIG. 5. Two of the primary (makeup) compressors. J. L. Kaspar, plant superintendent, in right background. Rough vacuum pumps in left background.

the stem and seat can be pulled without breaking the vacuum. Orientation of this type valve is quite critical because without the bellows-seal liquid can flow into the bonnet space and cause cool-down of the stem packing and subsequent leakage. The most critical portion of reworking a valve, no matter which type is used, is that any seals or joints within the vacuum space have to be leak tight. This means they have to pass a helium mass-spectrometer leak detector test when at operating temperature. The valves in the liquid nitrogen lines were conventional extended stem type and were placed outside of the vacuum and were insulated with expanded polystyrene.

A number of 330 hp natural gas driven, direct connected integral compressors were skid mounted along with all the refrigeration condensers, adsorbers, liquefier components, heat exchangers and liquid nitrogen and hydrogen Dewars for shipment to the job site.

Fig. 4 shows a view of two of the 330 hp units and Fig. 5 is a view of two of the primary compressors. These package compressors are complete self contained compressor stations that can be moved with ease to other locations for reusage. The remainder of the plant was designed with somewhat the same philosophy in mind to insure ease of maintenance during operation. The plant actually contains two liquefiers and three purifier sections (only one of each shown on the flowsheet), thereby giving it flexibility and standby capacity.

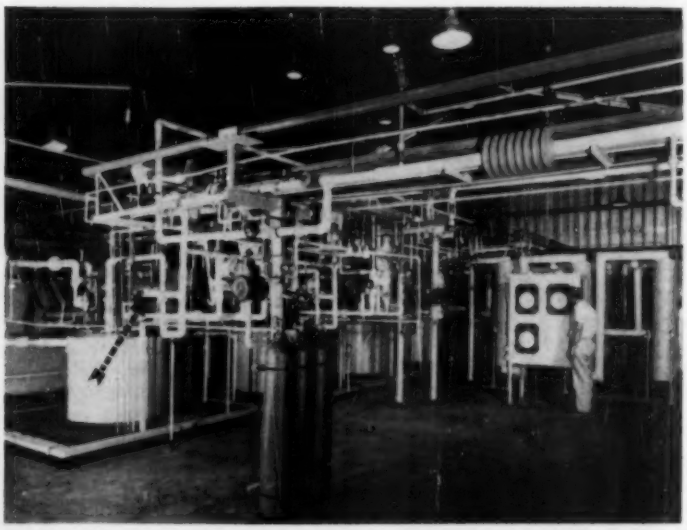


FIG. 6. Five vacuum insulated Dewars (top part visible only) containing two liquefiers and three purifiers. "K" bottles in foreground contain pure reference gas for use with the ortho-para analyzer. Operator is checking integrating flow meters which record plant production.

The liquefiers and purifiers (enclosed in vacuum Dewars shown in Fig. 6) were constructed, piped, instrumented, etc. so that they can be removed for maintenance during periods when the plant is producing at normal capacity. Shown in the picture behind the operator are the expanded polystyrene insulated refrigeration condensers. Arrow points to one of the valves packaged into the high vacuum insulated liquid hydrogen lines. It is of the solid body globe configuration with the bonnet seal and stem packing outside the vacuum space and at room temperature.

This versatility of being able to remove equipment to the repair building for maintenance during plant operations has certainly helped produce long runs before shutdown. These long runs necessitate a switch in liquefiers after 40 to 45 days because freeze-out is detected by observing the press-drop through the JT heat exchanger. When it becomes excessive the production is transferred to the other liquefier which has been pre-cooled sufficiently to eliminate any loss in production during switch over. Freeze-out in the JT heat exchanger is a common occurrence for Giauque-Hampson type liquefiers and doesn't present any specific problems other than need for warm-up so that the hydrocarbons, methane for the main part, can be melted and subsequently pumped out through the vacuum system. This is of course no reflection on the purification system in that it is very difficult to remove *all* impurities from a feed stream containing between 5 and 25 percent low boiling hydrocarbons.

The capability of being able to remove and replace the equipment by mechanical means rather than any soldering, welding, cutting, etc. created a few problem areas. Of course, the electrical leads to the catalyst and silica-gel heaters, instrumentation leads, capacitance probe leads, etc. all had to be to the National Electric Code, Class 1, Division 1, Groups B and D, so provided for some interesting tie-in problems at junction boxes at the equipment separator points.

Some difficulty was encountered with pipe unions because of the temperature and pressures involved. The most difficult were the return lines (purified H_2)

from the adsorbers to the refrigeration condensers. The gas in this line is at approximately 1850 psig and less than 77 K, thereby constituting a sealing problem for a mechanical joint. A fluro-hydrocarbon was used first but found to be inadequate because of deformation. That is if the joint were tightened cold, the material would deform when warmed up and would have to be re-tightened when cooled down. This presented undesirable problems in that the union had to be tightened at 1850 psig and 77 K and yet the insulation on the union had to be readily removable and yet provide a vapor barrier to prevent condensation by air. By machining copper ring gaskets to close tolerance and loading them to a calculated amount warm, it was found that the unions could be recycled any number of times without leakage. The insulation is now installed in a permanent manner and only removed when an adsorber has to be removed from its insulating Dewar for repairs.

The liquid hydrogen and nitrogen storage vessels are of the Dewar type. That is they are double walled with the annular space filled with −80 mesh perlite and evacuated to a pressure of 10 to 50 microns of Hg absolute before cool-down. The only difference in the Dewars is that the hydrogen unit has reinforcing rings in the inner vessel to allow for pump down and purge of the unit with the remainder of the hydrogen system. Liquid level sensing of the hydrogen is more critical because of its density (.58 lb per gal) and a very accurate oil filled manometer is used in place of the conventional differential pressure gage used on the nitrogen Dewar.

The oil carry over from the recirculation compressors is removed as it would freeze out in the upper (warmer) liquefier heat exchangers. Separation is first made in a scrubber filled with stainless steel "chore-girl" cleaning pads. Final clean-up is accomplished in an adsorber containing glass-wool, activated charcoal, and molecular sieve.

The liquid hydrogen road transportable Dewars were designed and constructed to meet Stearns-Roger specifications. These units were designed to transport 6000 gal of liquid hydrogen and for a maximum operating pressure of 50 psig. It is interesting to note that the trailer, without the tractor, weighs approximately 38,000 lb, yet the 6000 gal of hydrogen weighs only 3480 lb. This unbalanced ratio stems from the fact that the trailers are also of the Dewar type and considerable weight is provided by the double walls and insulation. These trailers have seen considerable road service and were specified so that they could be used in all states and be within legal clearances and axial loadings.

Operation

The significant aspects of the plant operation to date have been a safe, reliable, trouble-free operation allowing for production of a quality product in excess of that originally required by the customer.

Safety is considered of prime importance as it was when taken into consideration throughout plant design and equipment selection. Employees attend one safety meeting a month where emphasis is placed on the correct handling of liquid hydrogen and a detailed understanding of all phases of the process. A safety committee periodically reviews the entire plant and makes recommendations for correction of any unsafe condition or operation. The facility has operated since 1957 and to date has not incurred a lost time accident.

All plant maintenance has been of a minor nature resulting in continuous relatively trouble-free performance periods of 24 hours a day, 7 days a week for up to 67 days without shutdown. Most operating difficulties have been encountered during start-up when precise temperature profiles are hard to obtain; however, once the plant is stabilized, production normally continues in a smooth manner. Throughout the operation the quality of the product has been well above the specification of 95 percent para liquid hydrogen.

Plant output is flexible and has successfully varied to meet the changing demands of users in the western states. Safe transportation has been achieved by highway tractor and trailer combinations, and the driver is accompanied by a technician to handle any unforeseen emergency, should the need arise.

Use of refinery off-gas instead of base raw materials eliminates the need to manufacture hydrogen gas and thus greatly reduces investment requirements, operating costs and phasing-in problems at start-up time.

Liquid hydrogen appears more and more likely to play the dominant role in future space vehicles, with the result that programmed usage of this fuel is expected to be far in excess of that envisioned just a few years ago. The demonstrated reliability of this production facility, based upon refinery off-gas has played a significant role in preparing our technology for the increased demands ahead. ★ ★ ★

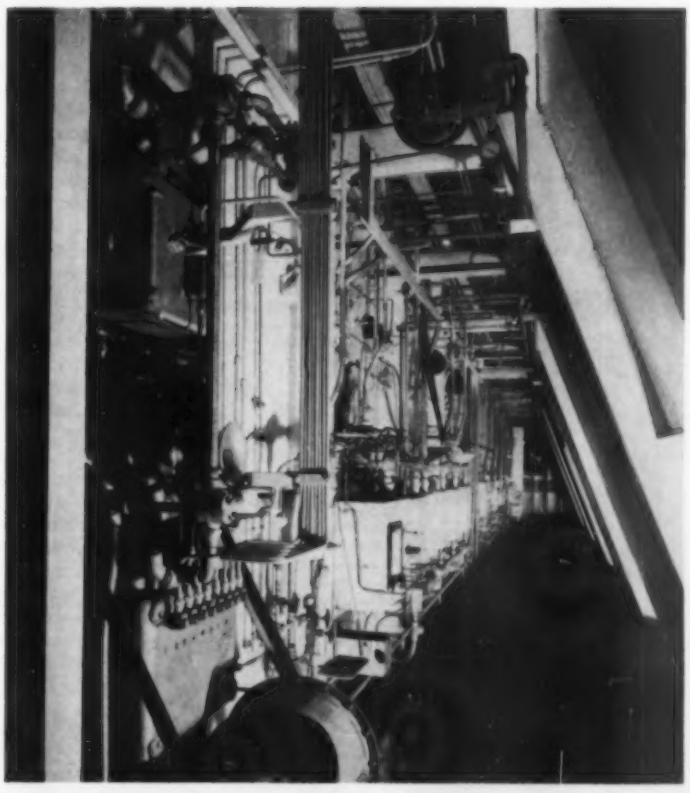


FIG. 7. Explosion-proof electrical work, pressurized enclosures for instruments, and the fire wall (right).

BRUNNER C. BARNES,
Consultant,
Barnes & Click, Inc.,
Dallas, Texas

C. P. STANLEY,
Vice President,
Dresser Engineering Co.,
Tulsa, Oklahoma

GEORGE E. HAYS,
Manager, Advanced Engineering Section, Research & Development Department, Phillips Petroleum Company, Bartlesville, Oklahoma

Question:

How low for natural gas

INDUSTRY FORUM

BRUNNER BARNES

LOW TEMPERATURE OPERATIONS for liquid-gas separation and absorption steps in natural gas processing facilities are gaining wide acceptance. New process designs frequently specify that these operations will be carried out at temperatures between 40 F and −20 F.

In general, the operation of liquid recovery facilities at low temperatures will improve the efficiency of condensation of the heavier components in the feed gas. Generally the increase in recovery will be obtained with a higher degree of selectivity so that it is easier to obtain liquid products of the required purity. Low temperature operations may therefore result in a process design giving:

Higher liquid product recovery efficiency,
Reduced absorption oil circulation rates,
Reduced absorption oil molecular weight
Reduced operating pressures,
Reduced heating and cooling requirements, or,
A combination of these benefits.

If low temperature processing is profitable, *how low an operating temperature should be used?* This question is answered by evaluating investment and operating expenses and income for process facilities designed to operate at various low temperature levels. This economic evaluation to obtain the most profitable temperature for operation should consider several mechanical and process design factors peculiar to low temperature operations.

Some **mechanical design considerations** are:

1. Conditioning of feed stream to prevent the formation of ice, hydrates, wax, or emulsions which reduce operating efficiency at low temperatures; or provisions for the removal of these materials from the equipment by batch or continuous cleaning.
2. Design and operation of refrigeration facilities to obtain low temperatures. Generally the complexity and unit cost of refrigeration facilities will increase as the refrigeration temperature level is reduced.
3. Special equipment and insulation design requirements for low temperature operations. For example, special

Continued Page C-14

processing temperatures?

W. W. BODLE,
District Manager,
J. F. Pritchard & Co.,
Chicago

Leading process engineers discuss trends in processing temperatures for hydrocarbon recovery.

HAROLD W. BARBER,
Chief Process Engineer,
Natural Gasoline Department,
Phillips Petroleum Company,
Bartlesville, Oklahoma

OVID C. BAKER,
Assistant to the Manager
Field Research Laboratory
Socony Mobil Oil Co.,
Dallas, Texas

C. P. STANLEY

DURING THE PAST SEVERAL YEARS, the trend in natural gasoline extraction plant design has definitely been away from atmospheric temperature absorption plants to refrigerated absorption plants. This trend has been caused primarily by economic considerations, as the value of fuel gas has increased, and as the general economics of this industry has forced designers and operators to look for more efficient and cheaper methods of LPG production.

The big advantages of refrigeration over atmospheric temperature extraction are the saving of plant fuel, reduction in capital investment, reduction in operating labor, and reduction in operating difficulties due to absence of water. Operation of this type plant lends itself to reduction in manpower requirements since no steam boilers are required, which often require constant attendance by state law. Since no stripping steam is used no water is introduced and gas leaving such a plant requires no further dehydration.

In setting up the design of this type plant the variables influencing the degree of refrigeration used are: (a) absorber pressure, (b) richness or content of gas, (c) depth of extraction required, (d) value of fuel gas and other utilities.

It is generally conceded that in a single still system 155 to 160 mol wt oil is the heaviest practical to employ without use of steam or other stripping medium. The lightest oil practical is that which will not give excessive losses at the absorber pressure and temperature. In most gasoline plants this is not below 125 mol wt. Somewhere in the vicinity of 300 lb is the optimum pressure from this standpoint with losses increasing as pressure goes down and also as pressure increases, since oil constituents are in the retrograde above 300 lb. About 800 lb is optimum for propane extraction since this is the pressure of minimum propane equilibrium constant for any given temperature.

The processing pressure is normally determined by gas pipeline requirements, and is usually 600 to 900 lb. The lower the processing temperatures used, the smaller the oil circulation, hence the lower the investment and operating

Continued Page C-16

Mr. Barnes Continued . . .

alloy steel must be used instead of carbon steel in equipment operated at temperatures below acceptable levels set by the applicable codes.

Process design considerations involve the development of accurate phase equilibrium and thermal data. The development of reliable vapor-liquid equilibrium ratios and heat content values for natural gas processing design calculations for low temperature operations may be quite difficult. These difficulties may increase as the temperature level is reduced.

Information presented in the Equilibrium Ratio Section of the Natural Gasoline Supply Men's Association Engineering Data Book, Seventh Edition, will be used as a basis for discussing some of the problems connected with the determination of equilibrium ratios for low temperature design calculations. Page 162 of this publication gives a discussion of the use of the convergence pressure concept in obtaining equilibrium ratios for paraffinic hydrocarbon systems. Equilibrium ratios are defined by pressure, temperature, and convergence pressure. Convergence pressure is determined by the composition of the liquid phase produced at equilibrium conditions.

Generally the convergence pressure will be reduced by the concentration of lighter fractions in the liquid phase. Reducing the operating temperature below 100 to 0 F, depending on the composition of the recovered liquid, will also reduce the convergence pressure in a system containing methane. Thus, as a general statement, a reduction in temperature for low temperature operations will reduce the convergence pressure for the system.

This reduction in convergence pressure due to the lowering of operating temperatures may be an important consideration in the design of natural gas processing schemes operating at high pressures. The primary separation and absorption steps in a plant processing gas for cycling are operations generally carried out at a high pressure in order to reduce cycle gas injection compressor requirements. The use of lower operating temperatures for these steps could call for a reduction in operating pressure in order to obtain a selective separation of liquids. This change would increase cycle gas injection compressor requirements, and could result in a reduction in profits from the operation.

Reliability of process design calculations for high pressure operations may fall off rapidly with reductions in operating temperatures. The discussion in the NGSMA Data Book points out that an accurate determination of the convergence pressure is necessary in order to obtain accurate equilibrium values when the ratio of operating pressure to convergence pressure is above 0.4. It is pointed out that equilibrium ratio values obtained for conditions where the ratio of operating pressure to convergence pressure is above 0.8 are very unreliable and should be used with extreme caution. This situation is complicated by the fact that the equilibrium values for low temperatures are generally extrapolated values based on rather sketchy experimental data. Thus, in high pressure - low temperature operations it is important to accurately define the convergence pressure; however, this value depends on the use of low temperature equilibrium constants which are of questionable reliability.

In high pressure-low temperature operations the equilibrium values for ethane and heavier fractions in the system increase rapidly as the operating pressure approaches the convergence pressure. Thus a change in convergence pressure caused by a change in feed composition may have a marked effect on the liquid-gas separation equilibrium conditions. Variations in operating pressure also has a marked effect on equilibrium conditions when operating at low temperatures and at pressure near the convergence pressure.

The pressure of carbon dioxide, hydrogen, sulfide, and nitrogen in the natural gas process stream complicates design calculations for low temperature operations. There is a scarcity of experimental data giving equilibrium values for these fractions in multi-component hydrocarbon system operating at low temperatures. Also, the relationship between the presence of these components in the mixture and convergence pressure is not clearly defined.

Difficulties are also experienced in the development of accurate thermal data for natural gas processing operations at low temperature conditions.

Since the cooling and heating of process streams is essential to the performance of a low temperature process this presents a serious design problem.

There is very little published experimental data giving information on the thermal properties of hydrocarbons in multi-component systems. Enough information is available to clearly show that component heat contents are a function of the composition of the system as well as temperature and pressure. Several correlations have been published for the determination of partial enthalpy values for the hydrocarbon components in a multi-component system. Calculated values using these correlations may show appreciable differences. Additional experimental data are needed to check the accuracy of these correlations, particularly in the high pressure-low temperature ranges. Experimental work on systems containing inert and acid gases in addition to hydrocarbons will also be of value.

The above comments may be summarized as:

Profits . . . from natural gas processing may be materially improved by the use of low temperature operations.

Mechanical considerations . . . may set an economic limit on the temperature level to be used in the low temperature operation.

High pressure processing operations . . . the minimum operating temperature level may be fixed by the approach of the convergence pressure to the operating pressure.

Difficulties in obtaining reliable equilibrium ratio and thermal data for multi-component systems in the low temperature-high pressure ranges present a barrier which should be removed by the development of additional experimental data points and improved correlations to predict performance in this region. This information will enable the designer to evaluate the performance and economic advantages of low temperature operations at high pressures. These evaluations should lead to the development of simplified process designs which will more fully utilize the benefits of low temperature operation. Simplified low temperature natural gas processing operations could materially increase profits from natural gas production and processing operations, particularly when these operations are carried out in conjunction with cycling, pressure maintenance, or miscible flood programs. ■

→

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cost for oil pumps, furnace, heat exchangers and coolers. The refrigeration compressor horsepower increases very fast, however, as the temperature is lowered and compression ratios increase. These factors must be evaluated very carefully to arrive at the most profitable plant, which may or may not be the plant with the lowest initial investment. Operating costs including fuel gas, electricity if purchased, water used, and operating labor must be evaluated against added investment which may reduce these items.

Capacity of the plant is also a factor in determining the best operating temperature, since the law of diminishing returns applies to the advantage to be gained by reduction in oil circulation below a certain point. A centrifugal oil pump for 50 gal per min for example may cost about as much as one for 100 gal per min. Heat exchangers are of course also much cheaper per unit of capacity in the larger sizes. In this connection it has been found that fixed tube exchangers are desirable in main gas to gas exchangers, since the temperature differences are small and fixed tube exchangers allow true counter-current flow.

Depth of propane extraction is many times a determining factor in whether economics of a plant looks good or bad. Often a plant extracting a larger percentage of propane is more profitable since operating labor may not be any greater for 80 percent propane extraction than for 30 percent. The profitability also is influenced to a great extent by the basis on which residue gas is sold. If it is sold on a Btu basis, as is now quite often the case, propane may cost as much as $0.02 per gal before extraction and processing, simply by reducing the heat content of the gas.

The advantages of refrigeration absorption plants are great enough that any atmospheric temperature absorption plant built in the future will be the exception rather than the rule. ■

W. W. BODLE

EARLY TECHNOLOGY of treating natural gas for removal of liquids was pointed toward the economical recovery of pentane and heavier components which enjoyed a good market as natural gasoline. Adsorption of the natural gasoline components on charcoal was rapidly replaced by absorption in circulating mineral seal oil as the desirable method of processing. Cooling water temperatures set the temperature of the oil absorption operation and dictated the recovery of by-product propane and butanes.

As the market for propane and butane grew, it became desirable to increase the recovery of these components. Existing plants added refrigeration equipment to lower absorption temperatures as the most economical method of effecting the increased recovery.

With the introduction of refrigeration to the industry for the purpose of increasing capacity, interest was stimulated in the advantages of incorporating refrigeration in the design of new plants. In recent years, as the size of extraction plants has increased and, with emphasis on the recovery of ethane from the natural gas, refrigeration must be incorporated into oil absorption systems for economical design. The only question is *"how low should processing temperatures be?"*

Lowering temperatures in oil absorption decreases the rate of oil circulation required to effect recovery of ethane and heavier products. The resultant savings in investment and utilities generally outweigh increasing costs and utilities due to the added refrigeration system and stricter water removal requirements on inlet gas. If temperatures are lowered sufficiently, the required oil circulation rate becomes zero and the process has changed from absorption to fractionation. The optimum economical temperature level will be dictated by consideration of such factors as gas pressure, gas composition, degree of recovery required, cost of utilities, and availability and cost of equipment suitable for low temperature.

Operation of absorption type plants treating natural gas with refrigeration levels down to −40 F are now commonplace. This temperature level is significant for two reasons. Propane, one of the products ordinarily produced in the plant, may be used as the refrigerant; low carbon deoxidized steel, costing very little more than ordinary carbon steel, may be used for equipment. At lower temperatures it is necessary to utilize another refrigerant such as ethane to supplement the propane in a cascade cycle or to use a relatively expensive material such as Freon. It is also necessary, at lower temperatures than about −50 F, to include nickel in steel equipment to prevent brittleness, adding appreciably to the cost over carbon steel.

Despite these −40 F to −50 F level blockades to the advantages of lower temperature processing, we expect to see many large capacity natural gas processing plants built soon employing lower temperatures. Don't expect a gradual trend in the movement to lower temperatures; rather look for an abrupt drop to the −150 F and lower levels.

Liquefaction and worldwide transportation of natural gas at −260 F liquid has been proved feasible by the Methane Pioneer's seven trips carrying pay loads of natural gas to London from Lake Charles, Louisiana. Commercialization waits only on negotiations of contracts for gas supplies at the most strategic locations.

Interest has been stimulated in liquefaction of natural gas during the summer and storage at −260 F for peak shaving use in the winter. The economics are clearly in favor of such a procedure in localities where demand rates are high and underground gas storage fields are remote. It is not unlikely that we will see liquefaction plants installed by East Coast utilities in the near future.

The U. S. Bureau of Mines is sponsoring a project at the present time to conserve helium which is presently carried by natural gas through transmission lines and lost as the gas is burned. This program will involve erection of 12 plants to remove a portion of the 12 million cubic feet of helium per day contained in 3 to 4 billion cu ft per day of helium bearing pipeline gas.

Recovery of helium from natural gas is effected by a low temperature separation process involving temperatures below −300 F.

Most of the gases to be treated for helium recovery are high in nitrogen content. It is simple and relatively inexpensive to add low temperature equipment for removal of

nitrogen. Removal of non-combustible nitrogen will relieve the pipeline systems and improve their capability to carry useful Btu's. Furthermore removal of nitrogen makes it possible to remove more of the heavier hydrocarbons without lowering the calorific value of the gas below contract limitations.

In carrying out the removal of helium and nitrogen, liquid ethane and heavier components will separate as the gas is being cooled to processing temperatures. These may be stabilized and taken as by-products from the operation, or in some circumstances, reinjected and transported in the gas stream for removal at a more desirable use point. In either case, low temperature operation for recovery and stabilization becomes attractive as the degree of recovery of ethane is increased over present practice.

Available low temperature thermodynamic data for process calculations involving helium, nitrogen and light hydrocarbons appears to be adequate; likewise, physical property data for design of equipment. Gaps in experimental data will have to be filled by correlations and extrapolations but hardly to any greater extent than is practiced for higher temperature work. Economic design of fractionation operations at low temperatures always involves a stringent analysis of optimum temperature levels. Consequently, the consistency and absolute value of data used must always be borne in mind.

Principals of equipment design, plant layout, interconnection, insulation, and materials of construction for low temperature hydrocarbon processing are well established through the art built up in conventional low temperature operations, such as air fractionation, and more recent developments centered around liquefaction and transportation of liquefied natural gas.

Laboratory and pilot plant experimental work dealing with low temperature natural gas processing will probably be centered on the problems of, and methods of dealing with, the minor components occurring in the gas. Moisture removal, CO_2 and H_2S removal by pretreatment of gas or by freezeout at low temperature and freezeout of relatively high melting point hydrocarbons, are some of the problems which are presently being investigated. ■

HAROLD W. BARBER

GEORGE E. HAYS

INCREASING DEMAND for natural gas liquids has caused most operators to revise their design practice over the past decade. Modern plants have higher recoveries of the lighter natural gas liquid components and, as a result, are much more complex than they were a few years ago. Below are some of the factors that have caused these changes.

Increased demand for NGL . . . over the past decade LP-gas sales have increased 10 percent each year to nearly nine billion gallons in 1959. Petrochemicals and use in motor fuel are responsible for much of this increase . . . The increase is expected to continue.

Increasing ethane extraction . . . ethane, until a very short time ago, was considered a design and operating nuisance by a natural gasoline plant operator. Now it is making rapid strides as raw feed for petrochemicals manufacture . . . This growth is expected to increase rapidly.

Lean gas processing . . . the increasing demand for natural gas liquids has forced suppliers to construct natural gasoline plants on natural gas streams which several years ago were thought to be too lean for economical processing. Plants on these lean streams must be cheap and efficient if they are to be profitable.

To meet the challenge presented by these and other factors, the design engineers studied various process schemes. As these systems were studied, the engineers found that their library of basic design data needed to be expanded. Many of these needs have been met by correlations such as the NGAA "K". One field that needs to be expanded is our enthalpy data. The following examples of design practices accentuate this need.

Trend to lower absorption temperatures . . . in order to obtain the more favorable extraction equilibrium at lower temperatures, increasing use of refrigeration has been employed. This trend has been intensified by the demand for lighter NGL and the availability of relatively lower cost refrigeration units. Often the design engineer found that to realize maximum fuel economy required a refrigeration plant. This economy becomes more and more important with the increasing value of residue gas. However, in considering the use of this lower temperature equipment, the design engineer found his basic enthalpy data lacking in the area where he needed it the most. The data needed to be expanded to cover a much wider range of temperatures. Also, he found it to be imperative that low temperature plant design had an accurate heat balance when he sought maximum economy.

Use of lower molecular weight oil . . . is obviously attractive from the standpoint that larger absorption capacity can be obtained per gallon or pound circulated. This trend has been augmented by the use of refrigeration in the plant. Again, the engineer found that his enthalpy data needed to be expanded to cover a wider range of components.

Use of computers in design . . . many organizations have high speed computers available for use by the design engineers. These have allowed the engineer to study many more process schemes in his search for optimum design and has resulted in more efficient plants. Here again the design engineer found his efforts to optimize the design hampered by his lack of enthalpy data. This could easily result in higher investment and operating costs for his company.

In summary, the writers would like to emphasize that there has been much reliable enthalpy data available to the design engineer. However, the range of this data needs to be expanded. Also, there are several methods available for estimating partial molal enthalpies and extrapolating test data. However, these methods often give widely differing results. The risks involved in using enthalpy data that is not accurate in the design of the modern, more complex natural gasoline plant can be costly. Additional experimental enthalpy data is needed badly. ■ ➡

OVID C. BAKER

ENTHALPY RESEARCH FOR THE PETROLEUM INDUSTRY . . . during the past several years operators of gasoline plants and refineries have discovered an increasingly serious shortage of reliable thermodynamic design data as process temperatures are reduced. In the last year only one or two gasoline plants have been built for atmospheric temperature operations. An increasing number of plants are being built with operating temperature around 0 F, and a few plants are operating at −40 F. The error in distillation column vapor loads may vary as much as 10 to 15 percent, depending on the enthalpy and equilibrium data used in the design. Variations of this magnitude in vapor load increase fractionator vessel costs by 7 to 10 percent. Reboiler and condenser duties may vary over the range of 5 to 20 percent, depending on the data used for calculation. Process engineers are accustomed to variations of this magnitude in their data. They normally accept as part of their job the responsibility for judging which enthalpy correlation is safest. This case history illustrates some of the problems and difficulties of the process engineer in making these estimates.

Case history . . . some operators have increased propane recovery in existing gasoline plants by the use of low temperature absorption. Recently a gasoline plant was revised to increase its propane recovery from 40 to 95 percent. At the same time the inlet gas to the plant was increased about 60 percent. In this plant both inlet gas and lean oil are cooled to −15 F before entering the 1100 and 1500 psig absorbers.

The heat loads for the inlet gas coolers and chillers were calculated using the enthalpy charts in the 1957 NGSMA Engineering Data Book, pages 121 through 132. The charts are the ones formerly used by the M. W. Kellogg Company. The heat loads were also calculated using a combination of Buthod's specific heat charts and Brown & Holcomb enthalpy charts. The plant cost was estimated for each case and found to be $595,000 more using Buthod's specific heats. The errors in enthalpy cost $1040 per MMcf per day capacity. Details are given in Table 1.

Since such a large sum of money was involved, the enthalpy of the gas to be processed was determined in the laboratory. The experimental enthalpies were very similar to those of Buthod, so the plant was built using the higher heat duties.

A comparison is made between the experimental specific heats of the 17.65 mol wt gas and those predicted by various correlations in use in the petroleum industry. Fig. 1 shows this comparison for 1500 psia from − 100 F to + 100 F. At 0 deg F the variation is twofold for specific heat values. Errors vary from +24 to −42 percent at 0 F and ±25 percent at 50 F. The Kellogg enthalpy charts in the NGSMA Data Book seem to give good values at ordinary conditions but at high pressures and low temperatures they should not be used.

The wide variation in predicted specific heats indicates that the people who are constructing enthalpy charts are being forced to extrapolate into areas where practically no experimental enthalpy data exists.

Very few experimenters are publishing enthalpy data for mixtures of hydrocarbons. Enthalpy research equipment is rather expensive for most universities, and the experiments are difficult to run.

An industry program . . . the problem of adequate enthalpy data has become of such importance to the industry that two years ago the NGAA assigned to its technical committee the responsibility for investigating the situation and reporting what could be done about it. In April of this year at the annual NGAA convention in Houston, Professor James Weber (University of Nebraska), gave the results of an investigation of all of the experimental data in the literature. A copy of his 52-page report may be obtained by writing the NGAA at 421 Kennedy Building. Tulsa 3, Oklahoma. At this same meeting the author presented a report on the economic value of an enthalpy research program to fill in the gap in our design data. The major conclusions reached in this study are summarized here:

An estimate was made of how much this lack of accurate enthalpy data is costing us. This involves looking at all the different kinds of heat exchange jobs in the industry. It also involves estimating the probable percent error in enthalpy in each case. At this point many different opinions

TABLE 1. Gasoline Plant A: Effect of Errors in Enthalpy on Cost of Plant with 0 F Absorption Temperature.

Ex. No.	Service	PSIG	Process Side Temp. Range, °F	Heat Duties, M Btu/hr: Kellogg	Heat Duties, M Btu/hr: Buthod & Brown-Holcomb	% Error in Kellogg Enthalpy	Differences in Plant Cost Due to Incorrect Enthalpy Values
E-201	Inlet gas-water cooler	1540	110 to 94	5,185	6,217	−16.6	
E-411	Inlet gas-absorber	1535	94 to 21	20,350	28,443	−28.4	
	residue exchanger	1512	1 to 85				
E-412	Inlet gas chiller	1530	21 to −15	11,359	17,004	−33.1	
	tons of refrigeration			947	1,418		
E-204	Inlet gas-water cooler	1130	110 to 94	5,411	6,006	− 9.9	$158,000
E-413	Inlet gas-	1125	94 to 17	26,451	33,321	−20.6	
	absorber residue exchanger	1100	−3 to 85				
E-414	Inlet gas chiller	1110	17 to −15	12,970	16,150	−19.7	
	tons of refrigeration			1,081	1,346		
Total	Heat duties, thousands Btu/hr			81,699	107,141	−23.7	
Total	Refrigeration, tons			2,028	2,764	−26.6	$298,000
	Cooling tower						20,000
	Installation and fees						119,000
	Total cost of enthalpy errors						$595,000
	Cost of enthalpy errors as $/MMefd capacity						$ 1,040

Ethylene Production

Licensed by: Stone & Webster Engineering Corporation

DESCRIPTION: Ethylene is produced from charge stocks ranging from refinery gas to gas oil. The flow diagram, and accompanying data are based on using refinery gas as feed. Ethylene and ethane are recovered by low temperature fractionation and the ethane is charged to the cracking heaters. Ethane conversion per pass is about 60 percent, with an ultimate ethylene yield of approximately 80 wt percent.

The pyrolysis gas-steam mixture from the cracking heaters is cooled, generating steam in transfer line exchangers, and quenched. The refinery gas and the cooled cracked gas are then compressed in three or four stages, desulfurized if necessary, and finally dried before entering the low temperature fractionation system at a pressure of about 500 psi gage. Ethylene and propylene or propane are used as refrigerants. The gas mixture is successively demethanized, deethanized to remove C_2 and heavier, and the resulting C_2 stream separated into ethylene and ethane. When ethylene product specifications require an acetylene-free product, catalytic hydrogenation of the acetylene is employed.

Propane and butane are also economical feed stocks in the U.S., whereas in Europe distillate feed stocks are more widely used. The C_3's, C_4's and gasoline produced as by-products of cracking can be important to plant economics.

TYPICAL MATERIAL BALANCE
REFINERY GAS FEED STOCK

FEEDSTOCK COMPOSITION

Constituent	Mol %
H_2	4.0
CO	0.4
H_2	22.6
CH_4	36.9
C_2H_4	6.6
C_2H_6	20.3
C_3^+	9.2
Total	100.0

MATERIAL BALANCE

Stream	MM Lb/Yr
Feed	296
C_2H_4 Product (98%)	102
Fuel Gas	133
C_3^+ Product	61

SERVICE FACTOR:
90 percent or higher

UTILITIES	Per Ton C_2H_4 Product
Steam @ 600 psi gage	15 M lb
Power	2.2 kwhr
Cooling Water 85F	177 M gal
Fuel Gas	11.5 MM Btu

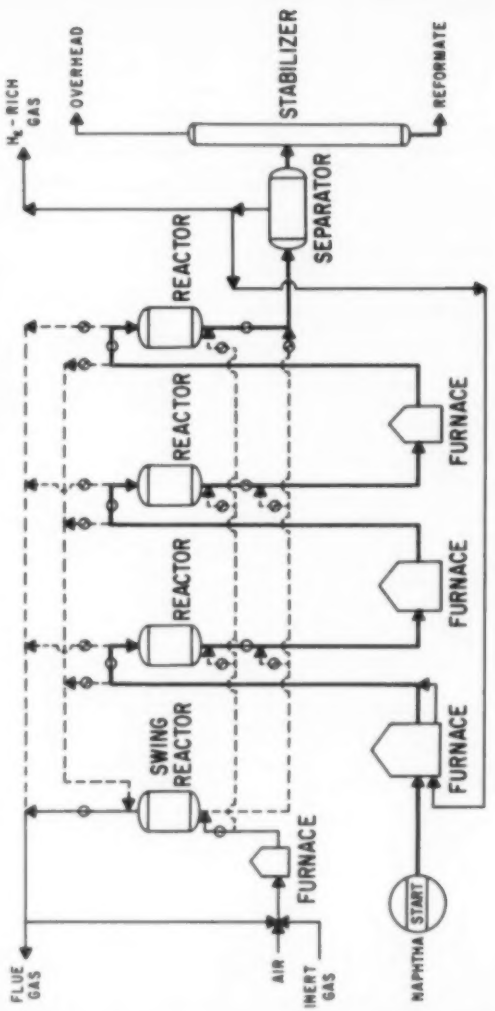
OPERATING PERSONNEL:
6 men per shift

INVESTMENT: (U.S. Gulf Coast, 1959)
For 100 MM Lb Per Year Plant— $7,000,000

ANNUAL MAINTENANCE:
Total Material and Labor — 4% of Investment

Ultraforming Process

Licensed by: Standard Oil Co. (Indiana)



Ultraforming Process

Licensed by: Standard Oil Co. (Indiana)

DESCRIPTION: Ultraforming is a regenerative fixed-bed catalytic reforming process which employs a platinum containing catalyst. Naphtha is combined with hydrogen-containing recycle gas and heated in a preheat furnace prior to charging to the first of a series of catalyst beds. Between each of the subsequent beds, there is an intermediate reheat furnace. Effluent from the last bed, after separation of gas and butanes, is a high octane gasoline blending stock with RON ratings up to 103, clear.

A distinctive feature of Ultraforming is the use of frequent catalyst regeneration made possible through a unique process design which includes a swing reactor. When catalyst activity in an onstream reactor declines, that reactor is temporarily replaced by the swing reactor. This switch is made by remote control of motor operated valves located as shown in the flow sheet. Reforming operations continue while catalyst in the isolated reactor is regenerated, in situ, with air and inert gas. After regeneration, the freshly regenerated reactor is placed back onstream and the swing reactor is again available to replace any other reactor in the system.

Ultraforming's low operating pressures, frequent onstream catalyst regeneration, low gas-recycle rate, and rugged catalyst combine to give high reformate and hydrogen yields, high octane potential, greater process flexibility, and lower catalyst and utilities costs.

Ultraforming units usually operate at a reactor pressure of about 200-300 psi and reactor inlet temperatures of 900-950 F. Gas recycle rates are in the order of 2500-4000 std cu ft per bbl of feed naphtha.

UTILITIES AND INVESTMENT COST.

Costs vary for individual units depending upon the quality of feed stock to be reformed and the octane number of the product produced. Estimates for specific installations will be furnished by the process Licensor on request.

OPERATING FACTOR.

About 95 percent.

TABLE 1 FEEDSTOCK INSPECTIONS

Feed	A	B	C	D
	MC Naphtha	Gulf Coast	Middle East Blend	Middle East Light Naphtha
Gravity, °API	55.5	51.1	57.2	62.3
ASTM Distillation, °F				
IBP	200	238	158	158
10%	230	263	212	185
30%	246	282	250	208
50%	262	304	284	230
70%	280	325	314	252
90%	316	357	347	275
EP	364	400	374	293
Paraffins, Vol. %	51.0	35	64.5	69.0
Olefins, Vol. %	0.5			
Naphthenes, Vol. %	36.0	51	19.0	17.0
Aromatics, Vol. %	12.5	14	16.5	14.0

TABLE 2 REFORMATE INSPECTIONS

Feedstock	A	B	C	D
C_5+ Ultraformate Research Octane,* Clear	102	103.5	101	101
ASTM Distillation, °F				
IBP	120	146	110	110
10%	168	204	150	140
30%	230	268	210	170
50%	265	296	270	210
70%	290	320	310	240
90%	326	372	360	300
EP	424	478	440	375
Gravity, °API	40.5	35.5	44.4	47.9
RVP, psi	4.0	2.9	6.8	7.2

*Octane numbers above 100 are on the Wiese extension of the octane scale.

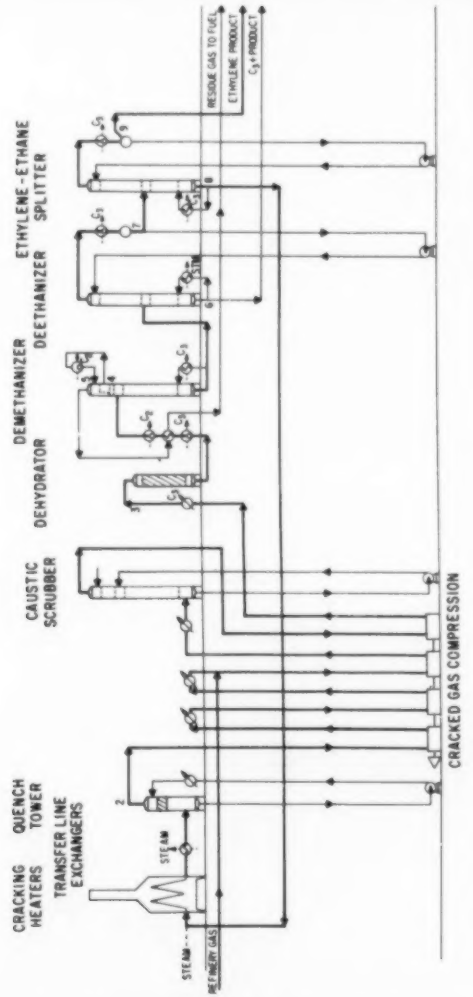
TABLE 3 MATERIAL BALANCES

FEEDSTOCK	A		B		C		D	
C_5+ Ultraformate Research Octane*, Clear	102		103 5		101		101	
YIELDS	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %	Vol. %	Wt. %
H_2	..	2.1	..	2.6	..	1.2	..	1.2
C_1	..	2.1	..	1.3	..	2.1	..	2.4
C_2	..	4.0	..	2.7	..	4.6	..	5.0
C_3	..	6.4	..	5.6	..	9.4	..	10.3
Total Dry Gas	..	14.6	..	12.2	..	17.3	..	18.9
nC_4	5.6	4.3	4.2	3.2	8.0	6.4	8.5	7.1
iC_4	4.3	3.2	2.9	2.1	5.7	4.3	6.1	4.7
Total Butanes	9.9	7.5	7.1	5.3	13.7	10.7	14.6	11.8
C_5+ Ultraformate	71.7	77.9	75 5	82.5	67.0	72.0	64.0	69.3

*Octane numbers above 100 are on the Wiese extension of the octane scale.

Ethylene Production

Licensed by: Stone & Webster Engineering Corporation



can be expected. However, in discussing a specific heat exchanger, it is surprising how quickly a group of experienced process engineers can agree on the probable percent error.

Almost 200 exchangers in refineries and natural gasoline plants were examined in detail. The composition of the process streams, the temperature and pressure range, and the existence and accuracy of experimental data were all considered in arriving at a probable percent error. For refineries the estimates were made by **S. T. Hadden,** an advisor to the NGAA Equilibrium Ratio Committee and the author. The ranges of estimated errors for various types of exchangers are listed here:

	Refineries	Gasoline Plants
Liquid-liquid exchangers	2- 4%	2- 4%
Liquid coolers and heaters	2- 7%	3- 7%
Exchangers with partial vaporization	4- 7%	5-25%
Condensers	5-12%	5-15%
Reboiler	5-12%	7-10%
Exchangers for hydrogen-hydrocarbon mixtures	7-30%	
Gas coolers with partial condensation		5-25%

The estimates of error are plotted in Fig. 2 to show their distribution. The comparison given below shows that the "all petroleum industry" estimates made by heat exchanger engineers and the author are in close agreement. Also shown is the marked increase in risk in designing low temperature gasoline plants without better enthalpy data.

	Mean Error	% of Heat Exchange Investment With Probable Enthalpy Errors of 5% or Less	15% or More
Heat exchange engr. "all industry" rating	4.3	58	4.3
The author's "all industry" rating	4.9	51	4.5
Refineries	5.8	40	5.3
Older gasoline plants	3.1	72	2.8
Low temperature gasoline plants	10.3	4	18.0

A 1960 Market Data Book published for the Hydrocarbon Process Industry gives an estimated value of $91,800,000 for heat exchange purposes in the United States in 1959. This amount can be distributed as:

Refineries	$43,400,000
Natural gasoline plants	5,400,000
Petrochemicals	43,000,000
	$91,800,000

If only refinery and natural gasoline plant exchangers are considered, the 1959 heat exchange purchases are estimated at $48,800,000. This cost, calculated with the estimates of error, gives an annual cost of enthalpy errors of $2,349,000.

Not all of the $2,349,000 estimated loss could be saved by better enthalpy data. Some designers would prefer to use safety factors that would reduce the possible saving. Other factors would also operate to diminish the savings. For purposes of this study, a utilization factor of 60 percent has been assumed. This gives a probable annual saving of (0.6) (2,349,000) = $1,410,000 before taxes, or $670,000 after taxes.

This first approximation showed possible savings to be large enough to justify a more elaborate evaluation. This new approach involves a determination of the dollar value of enthalpy research. The ideas and technique forming the basis of this evalution were published by **James Brian Quinn** in the March 1960 Harvard Business Review. Research produces technology but no profits. Profits are produced by the efforts and capital of various oil companies as they exploit technology. Profits measure the whole organization's effectiveness. The contribution of research technology is a separate thing entirely from the profit that may be made by exploiting it. The value of the technology is measured by how much money the industry, as a joint interest group of investors, would pay to own the technology at the time it is created.

An investor must look at technology as an opportunity to exploit potential value. The situation is just the same as an undrilled oil lease. Although the lease will require considerable capital investment and effort by the operator before it produces a profit, the lease has a value of its own. It is valuable because it presents an opportunity to exploit an oil reserve, and the lease bonus plus royalty payments measure the amount of its value to an investor.

The net revenue from exploiting the enthalpy research technology is estimated for each year over a reasonable period of time. The present value of these annual net cash flows is calculated using a percentage discount commensurate with the risk involved.

In order to make such a calculation, it is necessary to project petroleum industry operations into the future. No one can predict the future. The best that can be done is to construct a model that we think will fit the reality of the future in a reasonable way. Then we can evaluate the model. No two people would construct exactly the same model. However, the model can be adjusted easily to fit different projections and reevaluated.

The cost of overdesign of heat exchangers due to errors in enthalpy was estimated for refineries as: Various refinery units were examined in detail. Each heat exchanger was studied and the incremental cost of enthalpy errors estimated.

This data was combined as shown in Table 2 to arrive at the possible losses due to enthalpy errors in a typical refinery process scheme. This amounts to $2.24 per bbl of new capacity. But it must be increased to $4.48 per bbl of new capacity when adjusted for modernization of old facilities at the long term ratio of one dollar spent for modernization for each dollar spent for new capacity.

TABLE 2. Cost of Enthalpy Errors in $/bbl of New Refinery Capacity.

Unit	Capacity bbl/day	Exchangers Cost, $/bbl	Incremental Cost of Enthalpy Errors $/bbl
Crude distillation	35,500	$ 7.97	$0.28
Catalytic cracking	20,700	26.25	0.93
Catalytic reformer	8,400	34.60	3.45
Alkylation	3,400	95.00	3.46
Delayed coker	6,000	13.80	1.01
Gas plant Gas From	35,500	2.43	0.10
Refinery average	35,500	$45.50	$2.24

These data were used to calculate the refiners' annual savings until 1980 from an enthalpy research program. Annual savings for refiners varied from $260,000 to $516,000.

A similar procedure was used to estimate the probable cost of enthalpy errors for gasoline plants. This data is summarized in Table 3 along with estimates of the cost of enthalpy errors in other types of gas processing plants.

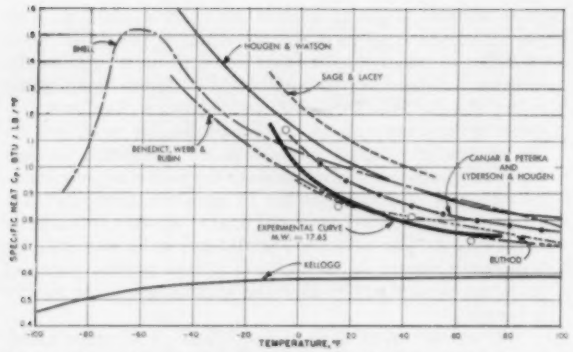


FIG. 1. Comparison of experimental specific heat for 1500 psia gas and various correlation values (mol wt of gas = 17.65).

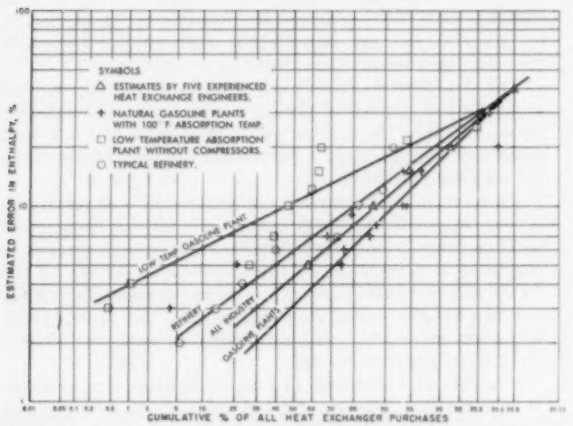

SYMBOLS
ESTIMATES BY FIVE EXPERIENCED HEAT EXCHANGE ENGINEERS.
NATURAL GASOLINE PLANTS WITH 100° F ABSORPTION TEMP.
LOW TEMPERATURE ABSORPTION PLANT WITHOUT COMPRESSORS.
TYPICAL REFINERY.
ESTIMATED ERROR IN ENTHALPY, %
LOW TEMP GASOLINE PLANT
REFINERY
ALL INDUSTRY
GASOLINE PLANTS
CUMULATIVE % OF ALL HEAT EXCHANGER PURCHASES

FIG. 2. Estimated percent error in enthalpy used in design of heat exchangers.

TABLE 3. Effect of Lowered Temperature on Cost of Enthalpy Errors in Gas Processing Plants.

	deg F	Incremental Cost of Enthalpy Errors $/MMcf/day Capacity
Cycling plant, absorption temp	100	330
Natural gasoline plant, absorption temp =	100	510
Natural gasoline plant, absorption temp =	20	680
Natural gasoline plant, absorption temp =	0	1,040
Refinery hydrogen purification plant	—230	4,600
Helium separation plant	—250	14,300

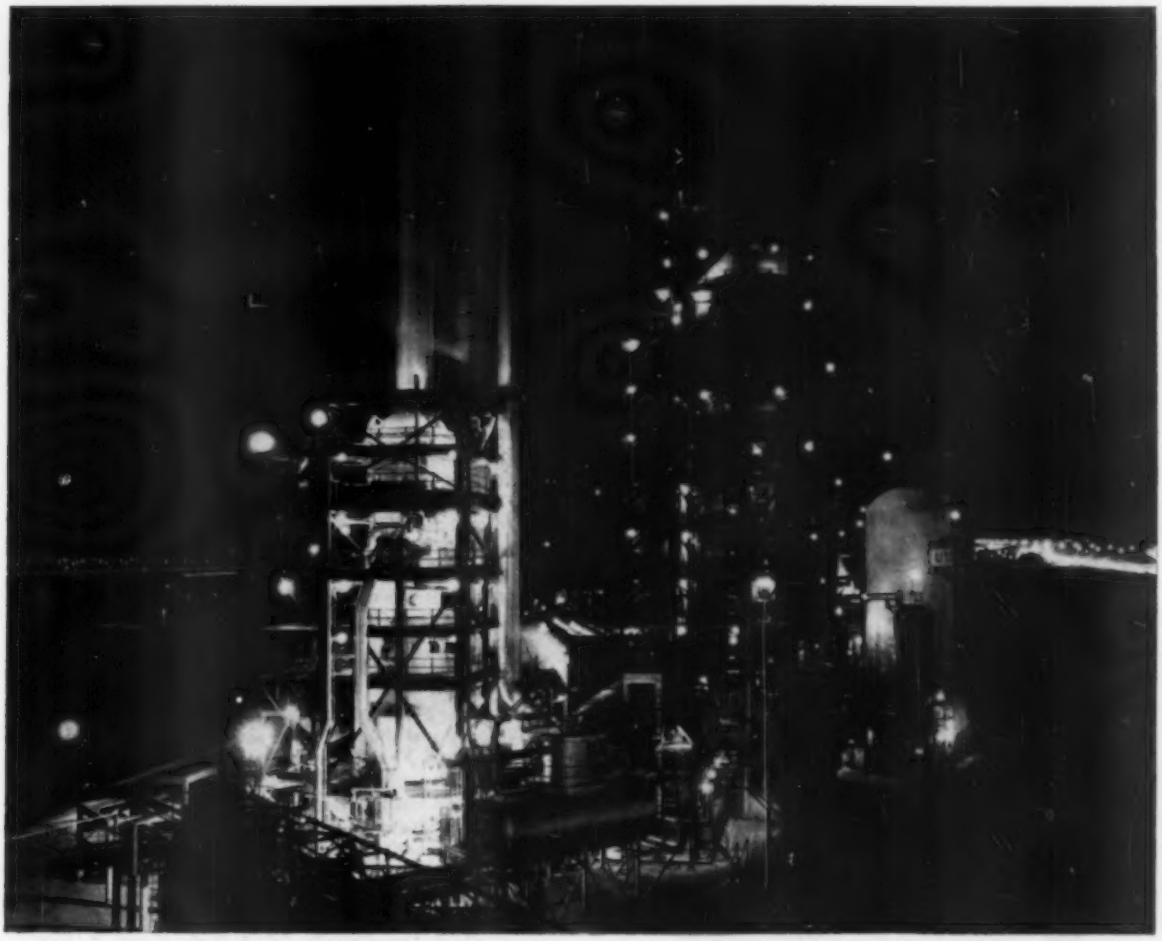
The various descriptive items making up our model for evaluation can now be combined to calculate the present value of a definitive enthalpy technology. The value of the improved enthalpy technology must be balanced against the cost of a research program. An estimate has been made by the NGAA indicating a research program cost of $37,500 annually over a period of eight years, or $300,000 total. This estimate is in substantial agreement with others that have been made. No useful results may be expected from such a research program for the first two years. After this one-tenth of the results of the work will become available annually. Thus at the end of the research program plant designers will be utilizing 70 percent of the results. In three more years the final correlations are expected to be in accepted use throughout the industry. Possible savings from the work have been adjusted to this schedule. Annual savings are discounted to the present at a rate of return of 20 percent after taxes. This high rate should adequately compensate for the risk involved.

The present value of the improved enthalpy technology is shown in Table 4 as $1,432,000. This amounts to $4.75 for each dollar invested, or $35 per dollar invested if undiscounted. The project can be operating out of profits after three years and two months. ★ ★ ★

TABLE 4. Present Value of a $300,000 Enthalpy Research Program. (All values in 1959 Dollars.)

Year	Possible Savings by Refiners	Possible Savings by Natural Gasoline Manufacturers	Total Savings* by USA Petroleum Industry	Cost of Research	Net Cash Flow	Present Value Net Cash at 20%	Cumulative Present Value of Net Cash Flow from Enthalpy Research
1960							
1961	516,000	304,000	0	37,000	(—37,000)	1.000	(—37,000)
1962	516,000	286,000	0	37,000	(—37,000)	0.833	(—67,800)
1963	516,000	304,000	82,000	37,000	45,000	0.694	(—36,600)
1964	516,000	304,000	164,000	37,000	127,000	0.579	36,942
1965	645,000	332,000	293,000	37,000	256,000	0.482	160,300
1966	516,000	373,000	356,000	37,000	319,000	0.402	288,600
1967	645,000	207,000	426,000	37,000	389,000	0.335	418,900
1968	516,000	456,000	583,000	41,000	542,000	0.279	570,100
1969	387,000	332,000	503,000	—	503,000	0.233	687,300
1970	516,000	311,000	662,000	—	662,000	0.194	815,700
1971	387,000	359,000	671,000	—	671,000	0.162	924,400
1972	387,000	406,000	793,000	—	793,000	0.135	1,031,500
1973	516,000	311,000	827,000	—	827,000	0.112	1,124,100
1974	516,000	311,000	827,000		827,000	0.093	1,201,000
1975	387,000	504,000	891,000	—	891,000	0.078	1,270,500
1976	516,000	297,000	813,000	—	813,000	0.065	1,323,400
1977	387,000	297,000	684,000	—	684,000	0.054	1,360,300
1978	387,000	386,000	773,000	—	773,000	0.045	1,395,100
1979	258,000	297,000	555,000	—	555,000	0.037	1,415,600
1980	258,000	262,000	520,000	—	520,000	0.031	1,431,700

*No useful results from enthalpy research may be expected for the first two years. After that time it is assumed that 10 percent of the possible annual saving will become available each year until full savings are possible in 1972.



Utah Oil Company's story tells why...

Modern Refineries Are Choosing B&W CO® Boilers

In May, 1958, a Babcock & Wilcox CO Boiler went on stream at Utah Oil Company's Salt Lake City refinery. Results: 1) Fuel-oil consumption has been about 55 to 60% of that needed for conventional boilers. 2) Incremental payout of the CO Boiler over that of conventional equipment is about 2.2 years, after taxes. Fuel-oil saving alone is enough to pay out the entire investment in 6.2 years, after taxes. 3) Maintenance costs are equal to or less than those for conventional equipment. Both water-side and fire-side tubes were clean after 24 months' operation. 4) The CO Boiler is operated as part of the cat cracking unit, with no increase in personnel.

The unit can generate 138,000 lb of steam per hour at 300 psig and 540 F. The boiler can operate on oil plus combustibles in the cat cracker regenerator flue gas, or on oil alone.

The CO Boiler was installed to take care of increasing steam requirements. The sensible heat of the waste regenerator gases was already removed with an existing waste heat boiler. Selection of a CO Boiler over conventional steam-generating equipment was made to utilize the waste combustible heat from the 17,500 bbl/D fluid unit, and to utilize existing manpower.

CO Boilers are setting similar performance and economy records in refineries throughout the world. The B&W CO Boiler is the only unit specifically designed for efficient burning of "waste" carbon monoxide. Check your own steam costs—then check with us and learn how a CO Boiler can cut those costs. The Babcock & Wilcox Company, Boiler Division, Barberton, Ohio.

CO-107

B&W

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BOILER DIVISION

For low temperature service to –50 F . . .

how to obtain ASTM A 333 C

Here is how you can get low temperature design materials in any quantity you want . . . when you want them.

IN THE SUMMER OF 1953, one of the large oil companies had a problem. They were faced with replacing portions of three lines damaged in a mechanical mishap. The footage of pipe was insignificant. They needed . . .

30 lineal ft of 2-in. Sch 80
20 lineal ft of 3-in. Sch 40
10 lineal ft of 8-in. Sch 40

The problem was they needed this pipe for service at minus 50 F. It was not in maintenance stock, and mill delivery was in the indefinite future. Minimum quantities from the mill were far in excess of the actual requirements . . . 500 to 700 ft of each size with delivery at mill convenience. The pipe was needed in three weeks.

Here's how the company solved the problem:

Sufficient quantities of each size to ASTM A 106 Gr B and ASTM A 53 Gr B were located with identifiable mill heat numbers. The pipe selected had the bare minimum physical and chemical requirements to warrant a trial at conversion. The mill test reports showed the following chemicals:

8-in. Sch 40 — Heat No. 620768-A 106 Gr B
C, 0.20; Mn, 0.65; P, 0.013; S, 0.032; Si, 0.16
3-in. Sch 40 — Heat No. R-7084-A 106 Gr B
C, 0.24; Mn, 0.60; P, 0.018; S, 0.020; Si, 0.20
2-in. Sch 80 — Heat No. 630899-A 53 Gr B
C, 0.21; Mn, 0.61; P, 0.018

Pipe was checked for grain size. By an examination of the chemical analysis and grain size the material appeared to be satisfactory for reclassification to ASTM A 333 Gr C. The material was normalized at 1650 F for one hour with the following results:

Grain size check showed a reduction in grain from size No. 4 to size No. 6.

Charpy keyhole notch impact tests (all test specimens 10 mm x 2.5 mm) showed:

8-in. Sch 40 at minus 50 F . . . Two specimens broke at 10 ft lb and one at 12 ft lb. (Average requirements for three specimens under code is 5 ft lb for this size sample.)

3-in. Sch 40 at minus 50 F . . . All these specimens broke at 8 ft lb.

2-in. Sch 80 at minus 50 F . . . Two specimens broke at 8 ft lb and one at 7 ft lb.

This pipe was then marked A 333 Gr C in addition to mill markings. It was used in this replacement problem at a cost that was trivial compared to the cost of mill marked pipe in the quantities required . . . plus the convenience of having the pipe on the job site when it was needed.

Here you have seen an actual case history of the successful reclassification by normalization of A 106 Gr B and A 53 Gr B to meet ASTMA 333 Gr C requirements. This was seven years ago. Since that time hundreds of tons of piping have been handled successfully in this manner . . . not only for maintenance but on many major construction projects requiring low temperature piping to minus 50 F.

MILLARD VAN BLARICOM *is a fabricating and welding consultant in Houston as manager of the engineering department of Houston Pipe & Steel Division, Midwest Piping Company, Inc. In welding since 1919, Van Blaricom was chief engineer with Houston Pipe & Steel from 1946 to 1956.*

from normalized A 106 B and A 53 B

Before we go into the "How to . . ." of this technique, let's review the code for low temperature steels to minus 50 F.

Code requirements are set forth in ASME Boiler & Pressure Vessel Code, Section VIII, Unfired Pressure Vessels:

Paragraph UG 84 . . . Sets down in detail impact testing requirements for low temperature service.

Paragraphs UCS 65, UCS 66, and UCS 67 . . . Give the scope, materials, and design of carbon and low alloy steels that are to be used at operating temperatures below minus 20 F.

Paragraph UNF 65 . . . Lists materials in Table UNF 23 together with deposited weld metal within the range of composition for materials in the table that do not undergo a marked drop in impact resistance at sub-zero temperature. Therefore, no additional requirements are specified for these materials when they are to be used at temperatures down to minus 325 F.

Paragraph UHA 51 . . . Lists materials made of high alloy and impact test requirements, although in general no impact tests are required for austenitic chromium-nickel steel of commercial grade.
Welds made in high alloy materials and the heat affected zones are subject to impact test requirements.

ASA-B31. 3 . . . Lists materials and their allowable stress values at temperatures as low as minus 325 F.

Paragraph 323, Materials . . . Requires that impact tests shall be made in accordance with Paragraph UG 84 of the ASME Boiler & Pressure Vessel Code, Section VIII, with exceptions and substitutions to this paragraph as noted.

The most commonly used material for piping operating below minus 20 F and above minus 50 F can be found in ASTM A 333 Gr C, Specifications for Low Temperature Steel Pipe. ASTM A 333 Gr 3, 5, and 4 are also given here to carry you to lower temperatures. We are concerned here only with ASTM A 333 Gr C pipe, A 420 Gr WPLC welded fittings, A 300 Gr 1 plate, and A 350 Gr LF-1 forgings.

Economics, when coupled with minimum footage or tonnage required from the mills, sizes and wall thickness, and delivery, may be sufficient reason to transform obtainable steel materials into ASTM A 333 Gr C or A 300 Gr 1 plate, etc., to meet the requirements for low temperature service.

Elements and Transition Energy Curves

Here are the elements commonly found in steels used for service down to a minus 50 F. Nickel, one of the most powerful agents for lowering the transition curve, is employed when going lower than minus 50 F and for this reason is not discussed.

Aluminum . . . Lowers the transition curve by decreasing the grain size, deoxidizing and/or tying up nitrogen.

Carbon . . . One of the most important factors. Promotes hardness, lowers ductility, affects welding when present in amounts greater than 0.30 percent. Involves special welding procedures. (As carbon increases, so increase transition ranges.)

Manganese . . . Added for deoxidation. Combines with sulfur to form manganese sulfide at high temperatures, which is quite harmless in steel and prevents hot shortness. In amounts from 0.30 to 1.50 percent, it decreases the transition range.

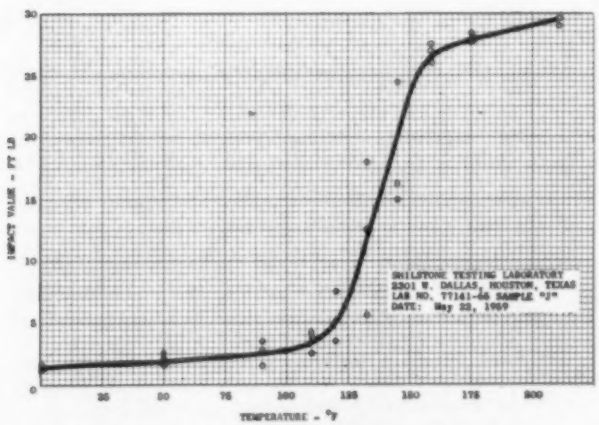
IMPACT VALUE - FT LB
TEMPERATURE - °F
SHILLSTONE TESTING LABORATORY
3301 W. DALLAS, HOUSTON, TEXAS
LAB NO. 77161-66 SAMPLE "J"
DATE: May 22, 1959

FIG. 1. Impact test results vs temperature for 4-in. steel pipe marked "J." Brittle failure occurred in manifold piping operation between + 30 F and —20 F.

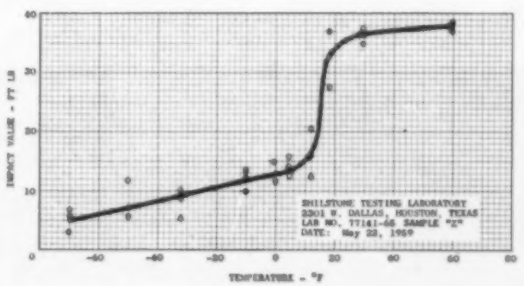
IMPACT VALUE - FT LB
TEMPERATURE - °F
SHILLSTONE TESTING LABORATORY
3301 W. DALLAS, HOUSTON, TEXAS
LAB NO. 77161-66 SAMPLE "Z"
DATE: May 22, 1959

FIG. 2. Impact test results vs temperature for 6-in. seamless steel pipe marked "Z." Material was selected for service at 0 F and failed.

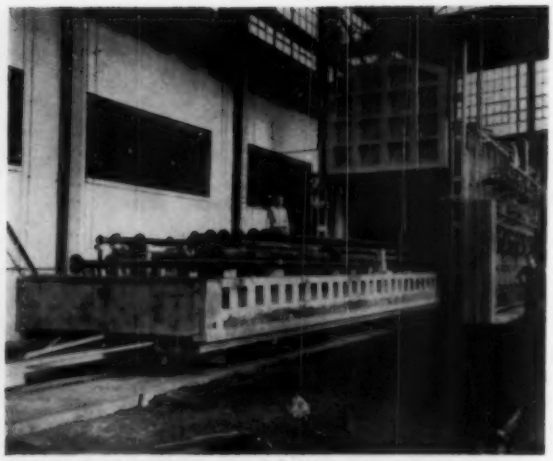

FIG. 3. Furnace and loaded car ready to charge to furnace for normalizing. Photo Courtesy: Midwest Piping Company, Inc., St. Louis, Mo.

Sulfur . . . Increases the transition range.

Phosphorus . . . In normal heat treating operations it diffuses too slowly to permit homogenization, causes banding, increases yield strength, lowers ductility, thus increasing transition range.

Silicon . . . Decreases the transition range in amounts less than 0.25 percent. Increases the transition range in amounts more than 0.25 percent. Normalizing at 1650 F has consistently lowered the transition temperature range, while heating in the stress relieving range of 1150 to 1200 F is ineffective, and tempering temperatures (500 to 800 F) are definitely harmful.

Transition Curve . . . The term transition temperature refers to the temperature at which a steel undergoes a change from a ductile state to an embrittled condition. This change is not a point property. When a plot is prepared of Temperature vs Charpy Impact Values for a given ferritic material, the Charpy values are seen to drop as the temperature is lowered. This gradual embrittlement continues until the transition range is reached. Through this range of temperatures a very noticeable drop in the Charpy results can be observed. At lower temperatures a further gradual lowering is present. For the more common ferritic materials used in design, the code accepts this transition range as being below minus 20 F. Some companies after evaluating the transition curves of common ferritic design materials have set into their design standards 0 F as the low temperature embrittlement limit.

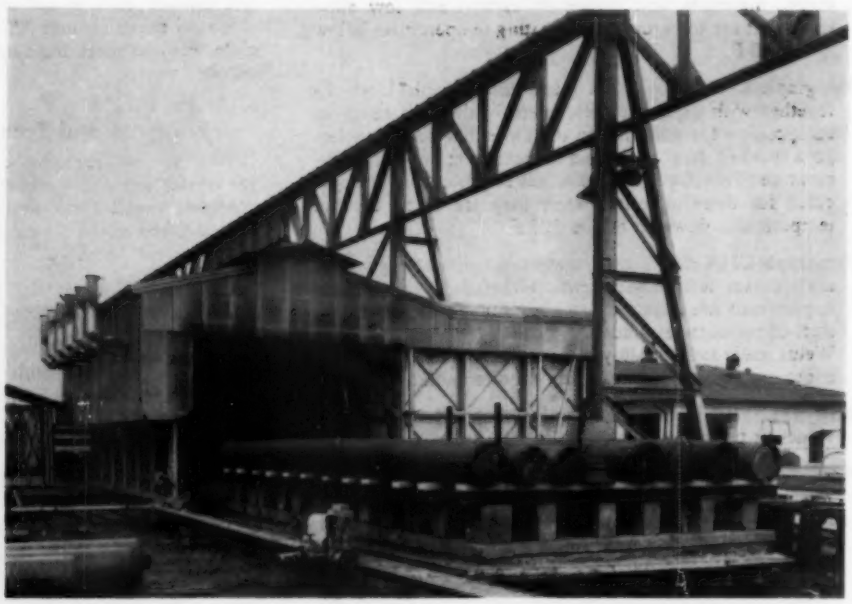

FIG. 4. Charge pulled from furnace and cooled. Note method of covering ends to prevent oxidation of inside of pipe. Photo Courtesy: Houston Pipe & Steel Division, Midwest Piping Company, Inc.

FIG. 5. An ammonia and a freon chiller fabricated from normalized materials to operate below —20 F. Photo Courtesy: Krueger Engineering & Mfg. Co., Houston, Texas.

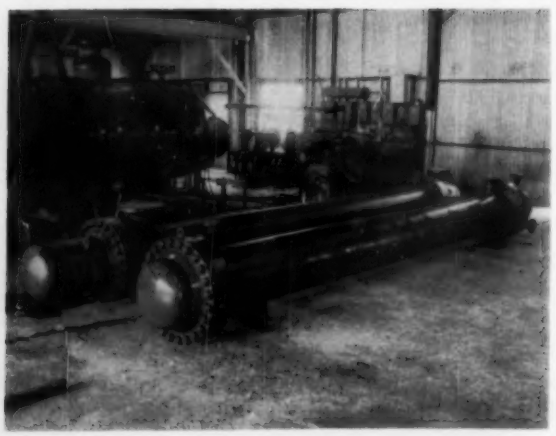

Fig. 1 and 2 illustrate the plot of Charpy Impact Values vs Temperature for two materials that actually failed in service under the conditions shown. Both of these materials exhibited transition temperatures above the code limit. This points up the fact that while the code is sound, the designer should be aware of the temperature effects and make a careful study of the operating conditions under which his design must function along with the geometry of the system.

In defining a transition curve each will be different de-

pending on the size of the specimen and the differences in grain structure within the sample. Larger specimens differ as geometrical restraint increases, such as in double or triple width specimens. Conversely, geometrical restraint decreases in subsize specimens, such as three-quarter, half and quarter size specimens. This is known as the size-temperature effect. The following table shows the allowable Charpy values under the code for various standard specimen sizes:

Impact Requirements

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens, ft-lb	Minimum Notched Bar Impact Value of One Specimen Only of a Set, ft-lb
10 by 10	15	10
10 by 7.5	12.5	8.5
10 by 5	10	7.0
10 by 25	5	3.5

Definitions

Killed Steels . . . The term *killed* indicates that the steel has been deoxidized sufficiently by the proper additions of ferrosilicon, aluminum, and other strong deoxidizers to lie perfectly quiet when poured into an ingot mold, so there is no evolution of gas and top surface of the ingot solidifies almost immediately.

The acid open hearth process is used almost entirely for the manufacture of killed steel.

Normalizing . . . Considerable confusion exists regarding the practices of normalizing and the process of annealing. Normalizing is the heat treatment of steel for the purpose of refining the grain size after hot working operations such as forging, hot bending, etc.

Wrought steel or forged steel is normalized by being heated to a point about 100 F above the transformation temperature range, holding at this temperature for a specific length of time — dependent upon the material section thickness — to allow the material to become thoroughly heated (soaked), *then removed from the furnace* and allowed to cool in still air.

Normalizing is generally performed before fabrication operations, welding in particular, but may be performed after fabrication if due consideration is given to the size and shape of the fabricated piece or pieces. In general, an intricate piece of fabrication will distort when the car is pulled from the furnace into the cooler atmosphere and will require a considerable amount of cleaning and straightening. Thus the additional expense must be taken into consideration.

Fig. 3 and 4 show piping material as pulled from the furnace after normalizing. Note the capped ends and the manner in which the smaller pipe is nesting inside of the larger pipe in the ones from which the end covers have been removed. By proper planning of the furnace charge the unit cost of normalizing can be kept to a minimum and will result in very economical ASTM A 333 Gr C material when properly tested and reclassified. The outer pipe will be covered with a light oxide scale much like fine

SOLD TO: Midwest Piping Co., Inc.
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Midwest Piping Co.
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DETAILED ANALYSIS REPORT

TUBE TURNS
DIVISION OF NATIONAL TUBE CORPORATION

LOUISVILLE, KY. 3/21/60
OUR ORDER NO. A3407 (2of3)
CUSTOMERS ORDER NO. 12937

DESCRIPTION	** HEAT TREATMENT	PHYSICALS OF MATERIALS FROM WHICH MADE: YIELD POINT PER SQUARE INCH	TENSILE STRENGTH PER SQUARE INCH	PERCENT ELONGATION IN 2"	PERCENT REDUCTION IN AREA	C	MN	P	S	SI	NI	CR	MO	CB	HEAT OR LOT NO	SPECIFICATION OF MATERIAL FROM WHICH MADE
14 2" X.H. Tee Part 21, Gr. A		42,400	70,600	33.5		.22	.69	.027	.024	.20		OK			T-5353	ASTM A106 Grade A
11 3" Std. Tee Part 20, Grade A		44,200	67,680	40.0		.22	.49	.009	.026	.12		NO			T-4715	STM A106 Grade A
14 4" Std. Tee Part20, Gr. A		40,500	67,400	35.0		.20	.45	.010	.023	.20		NO			T-4946	ASTM A106 Grade A
6 6" Std. Tee Part 20, Gr. A		45,700	67,100	42.0		.21	.64	.015	.024	.19		OK			T-4927	STM A106 Grade A
54 2" X.H. L.R. 90° Part 2, Gr. A		43,300	67,100	53.0		.26	.51	.010	.025	.17		NO			T-5240	STM A106 Grade A
38 3" Std. L.R. 90° Part 1, Grade A		51,250	72,090	35.0		.25	.80	.013	.024	.24		OK	except	26	T-5212	Carbon STM A106 Grade A
5 3" X.H. L.R. 90° Part 2, Gr. A		44,900	66,430	40.0		.22	.46	.015	.031	.19		NO			T-4440	STM A106 Grade A
42 4" Std. L.R. 90° Part 1, Gr. A		45,800	75,400	35.0		.23	.73	.014	.024	.19		OK			T-5284	STM A106 Grade A
59 6" Std. L.R. 90° Part 1, Grade A		42,000	68,800	42.0		.23	.49	.009	.016	.20		NO			T-5171	ASTM A106
2 4" Std. S.R. 90° Part 1, Gr. A		45,500	75,000	34.0		.24	.58	.016	.026	.18		NO			T-5269	Grade A STM A106
3 6" Std. S.R. 90° Part 1, Gr. A		52,400	74,600	36.0		.22	.65	.021	.027	.21		?			T-5841	Grade A STM A106
5 3" Std. L.R. 45° Part 5, Gr. A		57,230	79,040	32.0		.24	.76	.014	.021	.23		OK			T-5213	Grade A ASTM A106 Grade A

*STAND. ; ROUND TEST SPECIMEN USED ** N-NORMALIZED, A-ANNEALED, S-HEAT TREATED PER ORDERED SPECIFICATION

SUBSCRIBED AND SWORN TO BEFORE ME THIS 21st DAY OF March 1960

Milton P. Hanneken NOTARY PUBLIC My Commission Expires June 1, 1963.

I HEREBY CERTIFY THIS REPORT TO BE TRUE AND CORRECT ACCORDING TO RECORDS IN THE POSSESSION OF THIS CORPORATION

R. C. Campbell
R. C. Campbell, Metallurgical Department

FIG. 6. Mill test report giving the physical and chemical properties of fittings fabricated from ASTM A 106 Gr B. Chemical analysis has been review for suitability for reclasification to ASTM A 333 GR C by normalization.

SHILSTONE TESTING LABORATORY
INSPECTING AND CONSULTING CHEMISTS & ENGINEERS CARGO SURVEYORS
HOUSTON • NEW ORLEANS • BATON ROUGE • CORPUS CHRISTI

REPORT OF IMPACT TESTS

Laboratory No. 77141-11
Job. No. M
Date 11/10/56

Made on Steel Pipe
For Mr. M. Van Blaricom — Date of Test 11/9/56
5508 Arlington, Houston, Texas
Identification 10" ASTM A106, Gr. B (normalized at 1650°F 1 hr., air-cooled)
Specifications ASTM A-333, Gr. C -50° F Service

Testing Machine: Baldwin Universal — Test Method: Simple Beam (Charpy)
Linear Velocity of Hammer: 17.0
Effective Energy: 60 ft.-lb. — Specimen Type: ASTM, Type B
Specimen Size: 2.5 mm x 10 mm (½ Std. width)

Specimen No.	Identification	Specimen Width, "	Effective Section Depth, "	°F Temp.	Impact Value Ft. Lbs.
10.	10 *	.098	.197	-50	14.5
10..		.098	.197	-50	14.5
10...		.099	.197	-50	13.75

* Client's code for heat number.

Note: The above test results indicate that this material is suitable for normalizing to comply with ASTM A-333, Grade C for -50 F service

Photomicrographs are appended.

REPORT OF IMPACT TESTS

Laboratory No. 77141-66
Job. No. M
Date 5/26/58

Made on Steel Pipe
For Mr. M. Van Blaricom — Date of Test 5-20,23,26-58
5508 Arlington, Houston, Texas
Identification ASTM-A53 Grade B, Sch. 80 (normalized)
Specifications ASTM A333, Grade C, -50° F Service

Testing Machine: Baldwin Universal — Test Method: Simple Beam (Charpy)
Linear Velocity of Hammer: 17.0
Effective Energy: 60 ft.-lb. — Specimen Type: ASTM - Type B
Specimen Size: 10 mm x 5.0 mm (½ Std. width)

Specimen No.	Identification	Specimen Width, "	Effective Section Depth, "	°F Temp.	Impact Value Ft. Lbs.
3"	A*	.195	.197	-50	18.5
3"	A*	.197	.196	-50	19.5
3"	A*	.196	.197	-50	19.25

* Clients code for heat number.

Note: The above tests indicate that this material is suitable for normalizing to comply with ASTM A333, Grade C, for -50° F service.

Photomicrographs are appended.

REPORT OF IMPACT TESTS

Laboratory No. 77141-50
Job. No. M
Date 4/22/60

Made on Steel Welding Tee
For Mr. M. Van Blaricom — Date of Test 4/18/60
5508 Arlington Street, Houston, Texas
Identification 4" Fitting from ASTM A106, Grade A Pipe, normalized to conform to ASTM A420, Grade WPLC for -50° service
Specifications ASME

Testing Machine: Baldwin Universal — Test Method: Simple Beam (Charpy)
Linear Velocity of Hammer: 17.0
Effective Energy: 60 ft. /lb. — Specimen Type: ASTM Type B (Keyhole Notch)
Specimen Size: 10 mm x 5 mm (1/2 std. width)

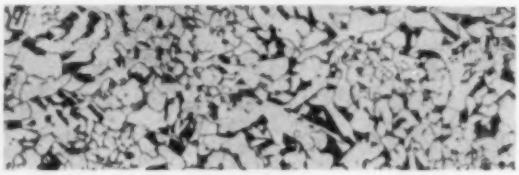
Specimen No.	Identification	Specimen Width, "	Effective Section Depth, "	°F Temp.	Impact Value Ft. Lbs.
A.	Sch 80, 4" Tee	.196	.195	-50	18.0
A..	Sch 80, 4" Tee	.196	.195	-50	18.0
A..	Sch 80, 4" Tee	.196	.195	-50	20.25

Note: The above test results indicate that this material is suitable for normalizing to comply with ASTM A420, Grade WPLC for -50° F service.

Photomicrographs are appended.

SHILSTONE TESTING LABORATORY
S. Bryan, Jr.

PHOTOMICROGRAPHS
Etchant: Nital
Magnification: 100X



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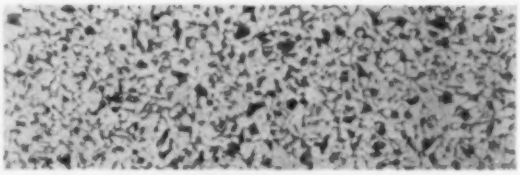
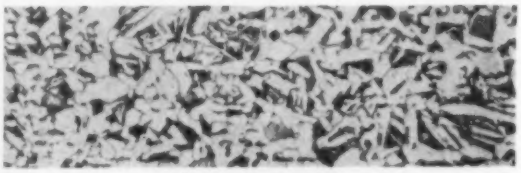


Normalized



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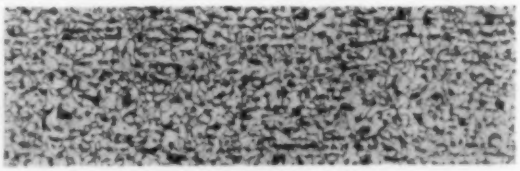
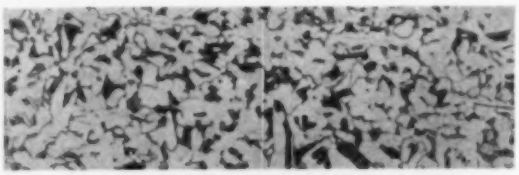


Normalized



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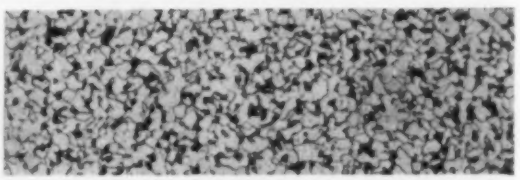
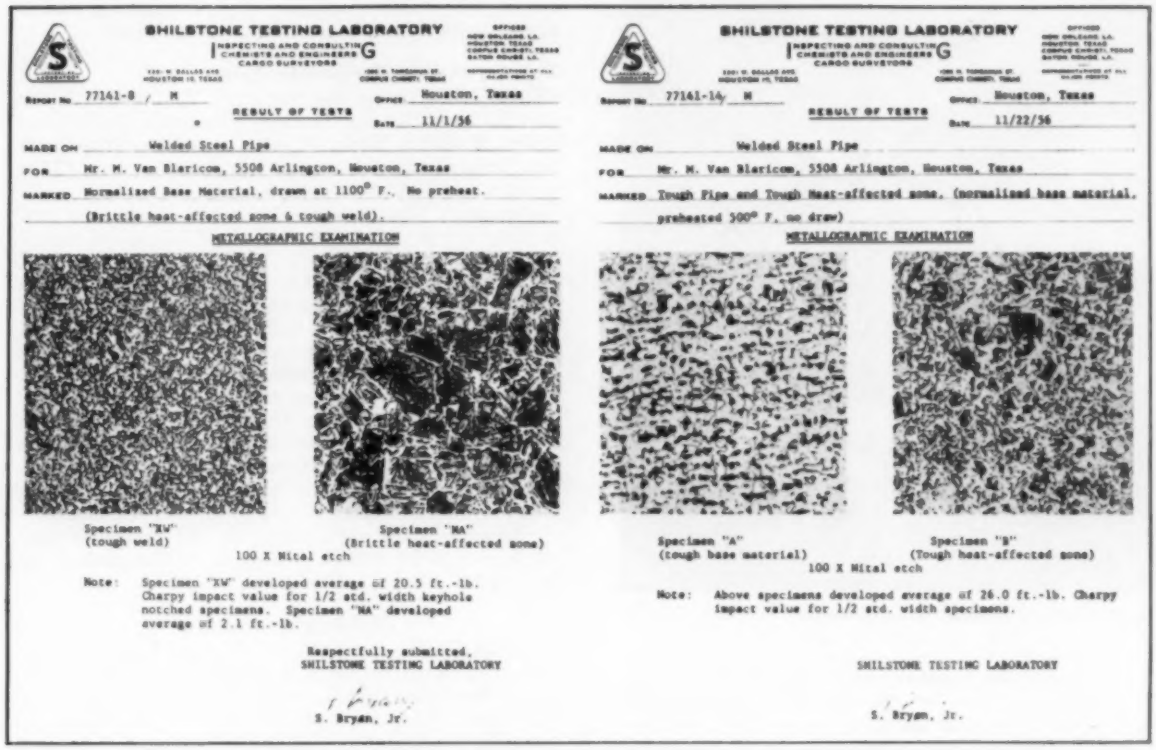


Normalized

FIG. 7. Here are the metallographic examinations of ASTM A 106B and A 53B pipe and an A 106B fitting in the "as received" and normalized condition along with Charpy reports on the normalized material. This material was all reclassified as ASTM A 333 Gr C and used under the code to —50 F.



SHILSTONE TESTING LABORATORY
INSPECTING AND CONSULTING CHEMISTS AND ENGINEERS
CARGO SURVEYORS

Report No 77141-8 / M
RESULT OF TESTS
Office Houston, Texas
Date 11/1/56

MADE ON Welded Steel Pipe
FOR Mr. M. Van Blaricom, 5508 Arlington, Houston, Texas
MARKED Normalized Base Material, drawn at 1100° F., No preheat.
(Brittle heat-affected zone & tough weld).

METALLOGRAPHIC EXAMINATION

Specimen "XW" (tough weld)
Specimen "HA" (Brittle heat-affected zone)
100 X Nital etch

Note: Specimen "XW" developed average of 20.5 ft.-lb. Charpy impact value for 1/2 std. width keyhole notched specimens. Specimen "HA" developed average of 2.1 ft.-lb.

Respectfully submitted,
SHILSTONE TESTING LABORATORY
S. Bryan, Jr.

SHILSTONE TESTING LABORATORY
INSPECTING AND CONSULTING CHEMISTS AND ENGINEERS
CARGO SURVEYORS

Report No 77141-14 / M
RESULT OF TESTS
Office Houston, Texas
Date 11/22/56

MADE ON Welded Steel Pipe
FOR Mr. M. Van Blaricom, 5508 Arlington, Houston, Texas
MARKED Tough Pipe and Tough Heat-affected zone. (normalized base material, preheated 500° F. no draw)

METALLOGRAPHIC EXAMINATION

Specimen "A" (tough base material)
Specimen "B" (Tough heat-affected zone)
100 X Nital etch

Note: Above specimens developed average of 26.0 ft.-lb. Charpy impact value for 1/2 std. width specimens.

SHILSTONE TESTING LABORATORY
S. Bryan, Jr.

FIG. 8. Metallographic examinations of the weld metal and the heat affected zone in normalized base metal. Tests were made with and without preheat.

rusting. This can easily be removed by sandblasting. If the ends are properly covered and kept covered until the pipe has cooled the oxide on the inside pipe can be eliminated where it will not be necessary to sandblast each piece of the charge.

It is therefore advisable to normalize before welding. Before welding preheat the weldment to prevent stresses and to prevent hard, brittle structures in the heat affected zones.

Stress relieving may be performed after welding, but our experience has not shown enough improvement in the structure to warrant the additional expense. We recommend stress relieving only as required by the code.

Annealing . . . This is the heat treatment of steel under controlled cycles of heating and cooling. As in normalizing, the material is heated to about 100 F above the transformation temperature range. The heating rate is set at a predetermined rate, held for a predetermined length of time, and *cooled in the furnace* at a specified rate to produce mechanical and metallurgical properties for a specific service condition. The controlled cooling results in a *larger* grain size and a soft or dead soft condition of hardness dependent upon the cycle specified. The result if cooled slowly enough produces a dimensionally stable, soft structure. Annealing in this manner is applicable to carbon (ferritic) steels. Austenitic steels such as the 300 series conversely require very rapid cooling to prevent carbide participation.

The annealing operation is in effect a stress relief for weldments, but it also affects the room temperature properties to such an extent that it may affect the properties seriously enough that the design should be rechecked against the loss of mechanical properties.

Here's the "How to . . ."

ASTM A 333 Gr C properties can be obtained from C, Mn, P, S, Si pipe, and A 300 Gr 1 properties can be obtained from carbon-silicon plate. It is also possible to obtain low temperature properties from other killed steels, provided the chemical and mechanical requirements will meet the low temperature specifications of the governing codes.

It should be noted that A 53 Gr A and A 106 Gr A both have lower specified minimum tensile strengths than A 333 Gr C.

In reclassifying A 53 Gr B or A 106 Gr B . . .

▶ Select from the mill test reports a fully skilled steel with a manganese to carbon ratio greater than 3:1 and with a total carbon content below 0.20 percent, if possible. It should be noted that this is not a requirement of the ASTM specification. The chemical requirements of A 333 Gr C are carbon, maximum of 0.30 percent; manganese, 0.40 to 1.06 percent; phosphorus, maximum of 0.05 percent, and sulfur, maximum of 0.06 percent.

The Mn:C ratio is a rule of thumb that is helpful in selecting material that will successfully reclassify. It has been found that when this ratio is greater than 3 the chances for success are good. However, material with a lesser ratio also may be successfully handled, but the chances of failure seem to be greater. As a matter of economics, use the high ratio material.

A typical mill test report is given in Fig. 6. A check of the chemical analysis of each fitting has been made and a notation indicates its suitability. All of the material marked "yes" was reclassified to ASTM A 333 Gr C. To show you the limitations of the "rule of thumb," the material in heat number T-4946 (a 4-in. std Tee) was given a metallographic examination .The grain size indicated a possibility

FIG. 9. A Baldwin Universal Testing Machine.

of success and the material was normalized. Fig. 7 gives the results of Test No. 77141-50 showing the metallographic examination of the material in the "as received" and "normalized" conditions and the results of the Charpy Impact Test. This material was successfully reclassified.

The steel must be made by either or both the open hearth or electric furnace processes.

The addition of silicon in amounts less than 0.30 percent results in a killed steel, as will the addition of aluminum in amounts of about 2 lb per ton of steel. The fully killed steel will have a lower ductile to brittle transition range than a semi-killed steel.

▸ Check the finishing operation, as a lower hot rolling operation also lowers the transition range because of finer grain size.

▸ Next check the steel for grain size so that you may compare the grain size of the unnormalized material against the material after it has been normalized. If the grain is too coarse or the structure heavily banded, it may not be practical to try to transform the material to the grain size necessary for low temperature properties; that is, a No. 2 or 3 grain size will probably not transform to a No. 6 or 8 grain size that normally shows good impact qualities.

Fig. 7 gives test results on ASTM A 106 Gr B and A 53 Gr B pipe, and an ASTM A 106 Gr B fitting.

▸ Having selected a suitable heat, proceed with the normalizing operation which will lower the transition range through transformation of grain sizes.

Do not *anneal* the steel, as this will tend to increase the transition range.

▸ After normalizing, check the grain size against the grain size of the steel in the unnormalized condition and note the structure, which should be homogeneous rather than heterogeneous. If the grain size and structure indicate the steel has transformed to the necessary qualities, you are now in a position to impact test.

▸ Using a Charpy keyhole notch test, check the normalized materials for the desired low temperature properties. Specimens for this test shall be obtained with the longitudinal axis of the specimen paralleled to the longitudinal axis of pipe or to the final direction of the rolling of plate.

Other Possible Reclassifications

Flanges and fittings in accordance with ASTM A 350 Gr LF-1 Steel Forging for Low Temperature Service and ASTM A 420 Gr WPLC Seamless or Welded Fittings for Low Temperature Service may be obtained from ASTM A 105 and ASTM A 181 respectively.

Flanges . . . When reclassifying A 105 flanges, the steel shall be made by either or both the open hearth and electric furnace processes.

Chemical requirements are carbon, maximum of 0.30 percent; manganese, maximum of 1.06 percent; phosphorus, maximum of 0.04 percent, and sulfur, maximum of 0.05 percent. Forgings are to be normalized or normalized and stress relieved. Impact requirements are the same as for A 333 Gr C pipe. Tests are to be made representing all forgings from the same heat. The test specimen, if cut from a flange, shall be cut tangentially from the flange portion approximately midway between the inner and outer surfaces and the center of the thickness. The manufacturer shall provide the necessary extra forgings or test block.

Fittings . . . When reclassifying A 181 fittings to meet ASTM A 420 Gr WPLC, proceed as for obtaining A 333 Gr C and A 350-LF1.

Welding Procedure

Welding is important in evaluating the brittle behavior of steel, as an improperly made weld promotes crack propagation, defects such as cracks, slag inclusions, or incomplete penetration. Weld finish is also of prime importance, as improper blending of the weld into the base material, ridges, ripples, or sharp angles are stress raisers and promote notch brittleness.

Root Passes . . . These should be made using the inert shielded gas method or the low-hydrogen type of electrodes. Succeeding passes should be made with low-hydrogen type electrodes either straight coated or iron powder coated.

Preheat . . . The transition temperature of mild steel is lowered with preheat, increasing from 400 to 500 F, which appears to be the optimum limit and has shown to be sufficiently beneficial to allow for the elmination of post heat. Preheat is of importance as it reduces the hard, brittle martensitic structure in the heat affected zone adjacent to the weld. The weld may be fine grained and tough, while the heat affected zone may be coarse and brittle. By preheating you impose a thermal barrier which slows the rate of cooling of the weld metal and the heat affected zone. This results in a finer grain in both the weld and heat affected zones . . . with increased ductility. Preheating also greatly reduces shrinkage stresses and the resultant "microcracking."

Fig. 8 gives test results on the weld and brittle heat affected zone of a weld made without preheat on normalized and tempered base material. Weld developed 20.5 ft lb absorbed energy on Charpy test at minus 50 F, while heat affected zone developed 2.12 ft lb. The same material with 500 F preheat and no post heat treatment developed 28 ft lb in the weld and 22 ft lb in the heat affected zone. All specimens were tested on Baldwin Universal Testing Machine (Fig. 9) with lineal velocity of hammer 17, effective energy 60 ft lb, specimen size 5 mm by 10 mm (half standard size), 6-in. pipe to ASTM A 106 Gr B, normalized to meet A 333 Gr C.

Notes on Charpy Tests

All our reports are based upon use of the keyhole notch.

A detailed explanation of the use of impact tests in determining the acceptability of steels for low temperature appears as Appendix III to ASTM A 333-58T. ★ ★ ★

Dr. J. M. Marchello, Oklahoma State University

CLIP/FILE

PETRO/CHEM

ALGEBRA | part 2

C. **Algebraic Equations**

Much of algebra is devoted to solving equations and systems of equations. An equation is a statement of equality between two or more quantities. The quantities on each side of the equals sign are *equals*.

The following general axioms are used in solving equations:

1. By adding the same number, or equal numbers, to equals (or both sides of an equation), the resulting sums will be equal.
2. By subtracting the same number, or equals, from equals the remainders will be equal.
3. Multiplying equals by the same numbers or equal numbers the products will be equal.
4. Dividing equals by the same number, or equals, the quotients will be equal. (Division by zero is excluded from algebra.)

In order to solve a given equation, it is usually necessary to employ one or more of the fundamental operations. The use of these axioms is illustrated in solving the equation

$$\frac{x}{2} - \frac{x}{3} + \frac{x}{4} = 2 - \frac{x}{6} + \frac{5x}{12} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Multiplying both sides of the equation by 12

$$6x - 4x + 3x = 24 - 2x + 5x \quad . \quad . \quad . \quad . \quad (2)$$

Combining terms

$$5x = 24 + 3x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Subtracting 3x from both sides of this equation

$$2x = 24 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Dividing both sides by 2 gives the solution

$$x = 12 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The degree of an equation is the largest sum of the exponents of the unknown quantities in any one term; for example, $x^2y + 2x + 3y^2 + xy = 0$ is of third degree, since the first term contains x^2 and y^1 making the sum of exponents 3. The equation $a^2x + aby + cx^2 = 0$ is of second degree, because the exponents of a, b and c are regarded as known or constant quantities and do not enter into the degree of the equation.

Equations of first degree like $ax + b = c$ are called linear equations. Second degree equations like $ax^2 + bx + c = 0$ are called quadratics. Third degree equations are cubics; fourth degree are bi-quadratics, etc.

PROBLEM 2

Composition of a Vapor-Liquid Mixture

A mixture of n-butane and n-pentane is at equilibrium and 3 atm pressure and 100 F. Calculate the compositions of the liquid and vapor.

Solution:

Values of K at 3 atm and 100 F are for butane, $K_B = 1.16$, and for pentane, $K_P = 0.363$.

Pertinent physical relationships:

$$y_i = k_i x_i$$

$$\Sigma y_i = 1$$

$$\Sigma x_i = 1$$

For the binary there are four equations and four unknowns:

$$y_B + y_P = 1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2\text{-}1)$$

$$x_B + x_P = 1 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2\text{-}2)$$

$$y_B = 1.16\, x_B \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2\text{-}3)$$

$$y_P = 0.363\, x_P \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2\text{-}4)$$

Analytical Method of Solution:

Substituting Equations 2-3 and 2-4 into Equation 2-1:

$$1.16\, x_{1a} + 0.363\, x_P = 1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (2\text{-}5)$$

Solving Equation 2-2 for the mole fraction of benzene in the liquid:

$$x_B = 1 - x_P \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2\text{-}6)$$

Substituting Equation 2-6 into Equation 2-5:

$$1.16\,(1 - x_P) + 0.363\, x_P = 1 \quad . \quad . \quad . \quad (2\text{-}7)$$

The following values are obtained for mole fractions:

$x_P = 0.20$ from Equation 2-7

$x_B = 0.80$ from Equation 2-6

$y_B = 0.93$ from Equation 2-3

$y_B = 0.07$ from Equation 2-1 or Equation 2-4

Solution by the Method of Determinants:

Rewriting Equations 1, 2, 3, and 4 in matrix form:

$$0 + 0 + y_B + y_P - 1 = 0 \quad . \quad . \quad . \quad . \quad (2\text{-}8)$$

$$x_B + x_P + 0 + 0 - 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad (2\text{-}9)$$

$$-1.16x_B + 0 + y_B + 0 + 0 = 0 \quad . \quad . \quad (2\text{-}10)$$

$$0 - 0.363x_P + 0 + yp + 0 = 0 \quad . \quad . \quad . \quad (2\text{-}11)$$

The unknowns, x_B, x_P, y_B, y_B, are found by setting up determinates from the coefficients of the unknowns, together with the constant terms arranged as a quotient.

The denominator or determinant of the coefficients of the system is:

$$\begin{vmatrix} 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \\ -1.16 & 0 & 1 & 0 \\ 0 & -0.363 & 0 & 1 \end{vmatrix} = 0 \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -0.363 & 0 & 1 \end{vmatrix} - 1 \begin{vmatrix} 0 & 1 & 1 \\ 0 & 1 & 0 \\ -0.363 & 0 & 1 \end{vmatrix} - 1.16 \begin{vmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ -0.363 & 0 & 1 \end{vmatrix} - 0 \begin{vmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{vmatrix}$$

$$= -1 \quad 0 \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} - 0 \begin{vmatrix} 1 & 1 \\ 0 & 1 \end{vmatrix} - 0.363 \begin{vmatrix} 1 & 1 \\ 1 & 0 \end{vmatrix} - 1.16 \quad 0 \begin{vmatrix} 0 & 0 \\ 0 & 1 \end{vmatrix} - 1 \begin{vmatrix} 1 & 1 \\ 0 & 1 \end{vmatrix} - 0.363 \begin{vmatrix} 1 & 1 \\ 0 & 0 \end{vmatrix}$$

$$= +0.363\,(0-1) + 1.16\,(1-0) - 0.421\,(0-0)$$

$$= 0.797$$

The unknowns are obtained from the determinates:

$$x_B = \frac{\begin{vmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -0.363 & 0 & 1 \end{vmatrix}}{0.797} = \frac{0.637}{0.797} = 0.80$$

$$= 1 \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ -0.363 & 0 & 1 \end{vmatrix} - 1 \begin{vmatrix} 0 & 1 & 1 \\ 0 & 1 & 0 \\ -0.363 & 0 & 1 \end{vmatrix} - 0 + 0$$

$$= +1 \left\{ 1 \begin{vmatrix} 1 & 0 \\ 0 & 1 \end{vmatrix} - 0 \quad -0.363 \begin{vmatrix} 0 & 0 \\ 1 & 0 \end{vmatrix} \right\} - 1 \left\{ -0.363 \begin{vmatrix} 1 & 1 \\ 1 & 0 \end{vmatrix} \right\}$$

$$= +1\,(1\text{-}0) - 0.363\,(0\text{-}0) - 0.363\,(0\text{-}1)$$

$$= +1 - 0.363 = 0.637$$

$$= +\frac{0.637}{0.797} = 0.80$$

$$x_P = \frac{\begin{vmatrix} 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 0 \\ -1.16 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{vmatrix}}{0.797} = \frac{0.116}{0.797} = 0.20$$

$$y_B = \frac{\begin{vmatrix} 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 0 \\ -1.16 & 0 & 0 & 0 \\ 0 & -0.363 & 0 & 1 \end{vmatrix}}{0.797} = \frac{0.741}{0.797} = 0.93$$

$$y_P = \frac{\begin{vmatrix} 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ -1.16 & 0 & 1 & 0 \\ 0 & -0.363 & 0 & 0 \end{vmatrix}}{0.797} = \frac{0.056}{0.797} = 0.07$$

In setting up the determinants for an unknown, the coefficients of the unknown are replaced by the corresponding constants from each equation.

Evaluation of the matrix is carried out in detail for the denominator. The general procedure applies for each of the determinates the unknowns. The method employed is known as an expansion by minors.

"The value of a determinant is the sum of the products obtained by multiplying each element of a column (or row) by its minor with a properly prefixed sign. The sign to be used with the element in the i^{th} row and j^{th} column is $(-1)^{i+j}$."

In resolving the fourth-order determinate into four third-order determinates the left hand column was operated on, $(j = 1, i = 1, 2, 3, 4)$. Only two of the four third-order determinates are non-zero. These were expanded to second-order determinates and evaluated according to the relation

$$\begin{vmatrix} a_1b_1 \\ a_2b_2 \end{vmatrix} = a_1b_2 - a_2b_1$$

Try your hand at these two problems. Solutions will be published next month.

PROBLEM 3

The Water Gas Reaction

Carbon monoxide and steam react to give hydrogen and carbon dioxide. Assuming ideal gas behavior, calculate the equilibrium fraction of steam decomposed at a temperature of 1270 F and a pressure of 10 atm when the initial mixture contains 1 mole of CO_2, 2 moles of H_2O and 1 mole of CO. At this temperature the common logarithm of the chemical equilibrium constant is equal to unity.

PROBLEM 4

Dew Point of a Vapor Mixture

Calculate the dew point of a gaseous mixture containing 20 mole percent benzene, 30 mole percent toluene, and 50 mole percent O-xylene at 1 atm total pressure.

CLIP/FILE

PETRO/CHEM

H. M. HOWARTH, *Senior Staff Engineer, Standard Oil Company (Indiana)*

Design factors and comparative costs for . . .

low temperature piping materials

PRIMARY CONSIDERATION in the selection of materials for low temperature is, **how to avoid brittle fracture.** Much has been published on the subject, yet we still cannot predict with complete reliability when brittle fracture will occur. This is because the presently measured physical properties of materials . . . tensile strength, elongation, reduction in area, and impact strength . . . can be misleading.[1,2,3] The most widely accepted theory of brittle fracture involves the fundamental properties of shear resistance and cohesive strength.[3,4,5] The big problem has been to devise a test which will evaluate these properties. In one of his most recent papers, Zaustin[2] made several logical proposals of how shear resistance and cohesive strength might be measured. The theory of brittle fracture, however, is outside of our scope here. It is brought to your attention to emphasize the fact there is need for much work in this field.

To date, brittle failure has generally been attributed to the notch sensitivity of the material at the operating temperature. Since notches or notch effects are present in all structures, including piping, various tests have been developed to evaluate the notch sensitivity. Unfortunately, all of these tests measure the properties of a material under the test conditions only, and not its behavior in an actual piping system where such factors as design, welding quality restraint, and stress distribution all have an influence. (Brittle failures have occurred at nominal stress levels where stress concentrations were present. Empty storage tank failures[6] are evidence of this.) Such tests are useful, however, because they permit comparison among the various materials and indicate those that are most likely to perform successfully under low temperature conditions. The most widely used test is the notched-bar Charpy impact test. The criterion for acceptance established by most code bodies is the arbitrarily selected value of absorbed energy of 15 ft lb in a 10 mm by 10 mm keyhole notched specimen at the service temperature.

Regardless of the area of ignorance about brittle failure, the designer uses the best tools available, which means he bases his design on the results of the impact test.

It is convenient to divide low temperature service into different temperature ranges when talking about materials. This is the case no matter whether you are working with piping, vessels or any other type of refinery equipment. Materials have been selected and tabulated here as piping specifications for each of the three temperature ranges.

Below —150 F

The first temperature range for which a specification has been prepared is for temperatures below −150 F.

Below −150 F there is not much disagreement on whether a material has acceptable low temperature properties or not. The big questions in this temperature range are which of the materials with good low temperature properties to use and how to put things together.

There are several non-ferrous materials, namely aluminum and copper and many of their alloys, that have acceptable low temperature properties at almost any low temperature. In addition, there is some data which would support the use of certain non-metallic materials at very low temperatures.[7] The non-ferrous and non-metallic materials will be discussed a little later.

Acceptable ferrous materials for temperatures below −150 F are many of the austenitic stainless steels and 9 percent nickel steel.

Low carbon 9 percent nickel steel can be welded and formed, and can have acceptable low temperature properties down to −325 F. The ASA B 31.3 — 1959 Code for Pressure Piping, however, requires impact tests on both the base material and welds if 9 Ni is used below −20 F.

The 9 Ni has had limited applicability in piping mainly because it was, until recently, available only in the plate form. There are now at least two mills which will furnish seamless 9 Ni pipe if a sufficiently large quantity is ordered. The cost for 3-in. and 8-in. Sch 40 seamless pipe varies from 55 to 85 percent of the cost of A 312 type 304 seamless pipe of the same size and thickness. As far as could be determined, the fitting, flange, and valve manufacturers do not as yet offer piping components in 9 Ni. It is possible, however, to weld 304 fittings and flanges to 9 Ni pipe using Inco-weld "A" electrodes and the resulting piping system would be considerably less expensive than all 304 systems. Differing opinions have been encountered as to what type of postheat treatment should be given such a weld to give it the best low temperature properties.

The 9 Ni pipe and plate must be double normalized for one hour at 1650 F and at 1450 F and stress relieved at 1050 F for two hours, as recommended by ASTM A 353, to obtain good impact properties. Inco-weld "A" electrodes and bare wire apparently make the best welds in 9 Ni materials. International Nickel Company reports that welds with good impact properties can be made without pre or

post heat treatment using Inco-weld "A" electrodes and wire. However, others[5] with considerable experience with 9 Ni insist that pre and post heat treatment are necessary to obtain welds with good impact properties. Also, the Piping Code suggests that 9 Ni be preheated to 300 F and post heat treated at 1050 to 1100 F for one hour, minimum.

International Nickel Company reports that welding has also been done successfully with 25-20 electrodes followed by two hours of stress-relief at 1050 F. However, these welds do not have strength of Inco-weld "A" welds or base material. There seems to be little reason for using this welding procedure.

Because 9 Ni pipe is available only in large quantities and because no ASTM pipe specification exists, it is impractical to consider 9 Ni as a standard piping material at this time. Therefore, the specification for ferrous piping materials for temperatures below −150 F, shown in Table 1, includes only the austenitic steels (essentially Type 304).

TABLE 1. Ferrous Materials — Below −150 F.

Bolting	ASTM A 193 (or A 320) Gr B8 (304) bolts ASTM A 194 Gr 8 (304) nuts
Gasketing	Type 304 spiral-wound
Pipe	ASTM A 312 TP304 seamless ASA B 36.19
Butt-welding Fittings	ASTM A 403 Gr WP304 ASA B 16.9
Castings	ASTM A 351 Gr CF 8 (304) or CF8M (316)
Forgings	ASTM A 182 Gr F304 Flanges to ASA B 16.5; S-W Fittings to ASA B 16.11

Discussion of "Below —150 F" Range

Bolting . . . There should be little disagreement with type 304 bolting (A 193 or A 320 Gr B8) for this temperature range. Bolting in types 321 (B8T) and 347 (B8C) is also acceptable and is readily available, but costs 10 and 20 percent more, respectively. ASTM A 194 Gr B8 (304) nuts are specified and apparently are satisfactory. B98 silicon bronze nuts have been used successfully with A 320 B8 bolts on air separation units. This combination is intended to eliminate any possibility of galling and should be considered as an acceptable alternate. (Table 6.)

Gaskets . . . Type 304 spiral-wound gaskets will give the most economical satisfactory flanged joint. Ring joints are also available and acceptable, but are not as economical. We have had some favorable experience with asbestos gaskets (sealed at the edges) in confined joints.

Pipe . . . ASTM A 312 type 304 piping is the least expensive of the several types of acceptable austenitic pipe available for low temperature service. For example, Type 304L costs about 21 percent more than Type 304; Type 316, about 64 percent more; Type 316L, about 85 percent more; Type 321, about 18 percent more; and Type 347, about 32 percent more.

Seamless pipe is specified because it is suitable for all applications. Electric fusion welded pipe can also be manufactured under ASTM A 312; however, the quality of electric fusion welded pipe can vary with the manufacturer and the Piping Code assigns it an 80 percent joint factor. Welded pipe costs between 85 and 90 percent as much as seamless pipe and would be suitable in the less hazardous or less severe applications. (Table 7.)

For larger pipe sizes and heavy wall thicknesses, consideration should be given to centrifugally cast pipe (made in accordance with Case 32 of Code for Pressure Piping).

ABOUT THE AUTHOR

H. M. HOWARTH, senior staff engineer in the standards section, Standard Oil Company (Indiana) general engineering department, Whiting, is chairman of ASA B 31.3, Refining Section, Code for Pressure Piping. He holds a BS in chemical engineering from Iowa State and has been with Standard of Indiana ever since his graduation from college in 1948.

Butt-welding Fittings . . . The predominate reasons for specifying ASTM A 403, Gr WP304 fittings are cost and availability. Types 316 and 347 fittings are available, but their cost is generally at least 20 percent more than Type 304 fittings. In larger sizes and heavier walls consideration should be given to cast fittings made to ASTM A 351 Gr CF8 and to ASA B 16.9. (Table 8.)

Castings . . . When using ferrous materials in this temperature range, we are limited to castings made from the austenitic steels. ASTM Specification A 351 with either Gr CF8 or Gr CF8M is listed. These two grades are the least expensive with the austenitic castings with good low temperature properties. Gr CF8M (316) is probably more readily available for MSS valves than CF8 (304), but the cost is the same. Many valve manufacturers have standardized on Type 316 because of its better overall corrosion resistance even though it is slightly more expensive to manufacture than Type 304. The reason for this is that the valve was designed and is used primarily for corrosive service. Where welding is to be performed on a casting, Type 304 should be specified because it is much more difficult to obtain welds with good low temperature properties on Type 316 materials.

ASA B 31.3 — 1959 presently requires that any austenitic casting to be used below −20 F be impact tested. The Piping Code Committee has assembled a considerable amount of data on the impact properties of centrifugal and static austenitic castings. The data indicates very definitely that cast austenitic materials that have been given a solution heat treatment can be exempt from impact tests. Based on the collected data, the Code Committee recently approved the deletion of this requirement for any such austenitic casting to be used at temperatures above −325 F. It seems probable that the American Standards Association and the code sponsors will also approve this change and that B 31.3 will be so revised.

Forgings . . . ASTM A 182 Gr F304 forgings are specified. Again, it is availability and price that dictate the choice of this material.

Here are several important factors pertaining to the piping components which are made from forgings and castings . . . **Flanges** . . . Apparently, it is necessary to make any flange used in low temperature service at least as thick as ASA B 16.5 thicknesses. Lightweight flanges do not have the strength to keep the gasket seated. It is also important to provide elasticity somewhere in each low temperature flanged joint. This can be done by providing an elastic gasket (this excludes solid metal gaskets) and conjunction with longer bolts. At our air separation unit our flange leakage problems have been minor. We have 2500-lb ASA flanges where others with similar units have had many leakage problems using 1500-lb ASA flanges. This difficulty probably occurs because the inside of the flange contracts more than the bolting thereby taking much of the load off of the gasket. Possible explanations of our better experience are the facts that we have used spiral-wound and sheet gaskets and that

the 2500-lb flanges require considerably longer bolts than the 1500-lb flanges.

Block valves . . . are made from forgings or castings and they require special design features for use at very low temperatures. As mentioned earlier, ASA B 16.5 flanges are necessary and austenitic valves with MSS SP-42 flanges will not always be adequate. However, other features of the MSS SP-42 valves have been found to be generally acceptable for low temperature service in the refinery.

Metal-to-metal seats almost always leak, especially at low temperatures. Our experience has been that we can tolerate or have learned to live with the small amount of leakage that occurs with the MSS gate valves used on our air separation unit. If it is necessary to have a tight shut-off on block valves, some arrangement should be worked out to provide a resilient material seating against metal. (Regardless of the seating materials, globe or Y-valves will generally give a tighter shut-off than gate valves.) The two resilient materials that have been used are Kel-F and teflon. Kel-F has generally been accepted as a better material at the extreme low temperatures and has been found to yield at −420 F. Teflon has been used successfully in valves down as low as −320 F; however, there is data[7] to support its use at even lower temperatures. One interesting modification that has been made to the MSS gate valve, in cases where a tight shut-off was needed, was to bond a 0.01-in. coating of teflon to the face of the wedge.

Another problem in valving for very low temperatures is the contraction and freezing of the packing with resultant leakage. A standard block valve must be equipped with an extension bonnet of stainless steel and a stem extension to bring the packing and handle outside of the pipe insulation. If the MSS valve with ASA flanges and extension bonnet can be used, valving costs will be comparatively moderate in the smaller sizes.

Relative Cost . . . To give the reader an idea of how piping systems of the various acceptable materials compare on an economic basis, comparative costs have been computed for the representative piping configuration shown in Fig. 1. The comparison for the temperature range "Below −150 F" is shown in Table 11 of the Appendix. The relative cost of a piping system made of the components specified in Table 1 is higher than any other listed; however, it is acceptable for almost any service. Table 11 indicates the economic incentive to make use of the other listed materials.

Comparative costs of bolting, pipe, butt-welding fittings, flanged gate valves, and flanges are shown in Tables 6, 7, 8, 9 and 10, respectively.

Welding for Below —150 F

Both the Piping and Vessel Codes require that impact tests be made on austenitic welds which are to operate below −20 F. This is another question that the ASA B 31.3 Piping Code Committee has been investigating. They recently assembled a considerable amount of data on this subject, hoping that they would be able to modify this requirement. However, they found the data conflicting enough to cause them to seek additional data which they hope will indicate a conclusion. Many engineers feel that a blanket requirement for impact tests on austenitic welds is incorreet and it can and should be modified in some way.

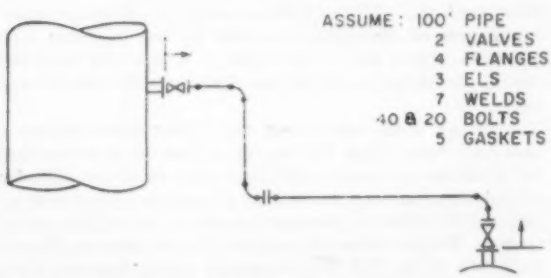


FIG. 1. Assumed piping configuration for comparative cost estimates . . . typical for all cases.

Amel Meyer of the Standard Oil Company (Indiana) has done a considerable amount of work on welds for low temperatures and his work indicates that impact tests need not be performed on welds made in Type 304 or 304L steel if Type 308 (20 Cr — 11 Ni) or 308L electrodes are used. Both his laboratory tests and extensive production experience have shown that welds produced by the inert-gas shielded metallic arc process with either Type 308 or 308L wire exhibit superior impact strength down to at least −325 F as compared to other common welding processes. Mr. Meyer feels that by using a Magne-Cage to check each weld made this way, one can be sure of good low temperature properties if the Magne-Cage reading shows between 2 and 6 percent free ferrite.[9] Earlier, conflicting data were mentioned which so far has prevented the B 31.3 Committee from modifying Code requirements for impact testing austenitic welds. To make the picture more complete, it should be reported that this data included a report of some 200 successful impact tests on fully austenitic welds.

The reader is also referred to a paper by Hansen[8] in which he has discussed most of the problems in welding for low temperature service.*

Non-Ferrous and Non-Metallic Materials

As mentioned earlier, aluminum and copper and many of their alloys have very excellent low temperature properties. Whether or not you use them in a refinery, depends on your philosophy of design for fire conditions.

There has been a reluctance on the part of refiners to use aluminum or copper and their alloys in hydrocarbon service on process units. The reason for this is the low melting point of these materials. The thought being that in the event of a fire, components made of these materials would readily fail and extend the fire. Plastics have not been used for the same reason. It is difficult to dispute such a policy when one remembers that there have been a large number of uninsulated brass piping components which have melted in refinery fires. It is not known whether these piping components contained any fluid at the time of their failure or not, or whether their failure added to the fire.

You've probably all heard of the old trick of being able to boil water in a paper bag. A similar situation exists as long as there is fluid in the piping system. The pipe metal temperature (even if exposed to flames) will not get very much above the boiling point of the fluid at the relief valve setting. After the fluid is gone, having been pumped out or vaporized, there is little cause for concern anyway because the failure will not greatly add to the fire. In addition, such items as teflon gasketing materials and valve packings are often used and will undoubtedly be destroyed before the aluminum or copper materials. Also, you undoubtedly have read lately where plastic pipe has been subjected to fire tests with gasoline in the line. Other oil companies have run fire tests on rubber hose. As long as the fluid in the hose remained, the hose did not burn. The conditions under which these tests were conducted are not known, but the results do indicate that perhaps aluminum, copper and plastics shouldn't be prohibited from all hydrocarbon piping on process units.

An even more important factor is that economics require that low temperature piping be insulated and insulation pro-

vides fire protection for the piping. The common low temperature insulations — vegetable cork, rock cork, and fiber glass — provide about ½ hour, 1 hour, and 1 hour of protection respectively. **There is no record in the literature of a failure of an insulated non-ferrous piping component.** It is the author's understanding that there were no failures of the cold lines to and from the spheres involved in the 1944 Cleveland fire (which was the result of a brittle failure). These lines were made of copper or copper alloys and were heavily insulated externally with cork.

The philosophy of design for fire conditions is not the subject here; however, it is hoped that this discussion will stimulate some new interest in this most important consideration for all refinery design. **Perhaps a result will be some fire tests on these materials or the disclosure of fire tests or fire experience.**

For those whose philosophy permits the use of non-ferrous and non-metallic materials in flammable service on process units, the following information is offered.

Plastics have been used in low temperature equipment as insulating supports, gasketing material, valve seats, and tank materials; however, adequate information is not available for optimum design in this area. A few results have been reported by Corruccini[7] and plastics may well become very important in future low temperature work.

Copper alloy piping components, except for valves, are more expensive than aluminum. Also, many of them are more difficult to obtain. Therefore, aluminum should be given first consideration if non-ferrous materials are acceptable. (See Table 2.)

TABLE 2. Aluminum Piping for Low Temperature Service.

Bolting	ASTM A 193 Gr B8 (304) bolts ASTM B 98 nuts
Gasketing	Type 304 spiral-wound
Pipe	ASTM B 241 Alloy M1A (3003) or Alloy GS11A (6061-T6)
Butt-welding Fittings	Aluminum Conforming to ASTM A 234, as applicable
Castings	ASTM A 351 Gr CF8 (304) or CF8M (316)
Forgings	ASTM B 247 Alloy GS 11A (6061-T6) Flanges to ASA B 16.5 dimensions

Discussion of Table 2

Bolting . . . The bolting was specified because of known good experience with these materials and skepticism that the galling problem associated with aluminum bolting can be resolved even with lubricants. If this galling problem can be solved, there is a considerable economic incentive for using aluminum bolting. (Table 6.)

Gasketing . . . Type 304 spiral-wound gaskets should give the most satisfactory joint. Spiral-wound aluminum gaskets are also available.

Pipe . . . Pipe is also available in a third alloy GS10A (6063), from one aluminum company, at an intermediate cost.

Sch 40 aluminum pipe made in alloys 3003 and 6061-T6 is adequate for 220 and 400 psi, respectively, in the 8-in. size. (The pressures were calculated assuming the aluminum piping installation was to be fabricated by welding.) This compares with 1335 psi for Sch 40-304 seamless pipe. In smaller pipe sizes the allowable pressures would be higher, and in larger sizes allowable pressures would be lower. As a general rule, Sch 40 6061 aluminum is suitable for about the same pressures as Sch 5 304.

Pipe in Sch 5 and 10 is available from at least one aluminum company and costs about 50 and 67 percent as much as Sch 40, respectively. Sch 5 and 10 aluminum pipe would be satisfactory for only low pressures.

Butt-welding Fittings . . . Sch 40 butt-welding fittings from aluminum alloy cost about the same as Sch 5 and 10-304 fittings.

Forgings . . . Aluminum weld neck flanges to ASA B 16.5 dimensions are also cheaper than 304 flanges. 3003 and 6061 flanges cost the same, so there is little reason to buy 3003. A comparison of the proposed aluminum flange ratings with the ratings of ferrous flanges is shown in Table 3.

TABLE 3. Comparison of Low Temperature Flange Ratings.

Material	ASTM Spec.	Alloy or Grade	Maximum Non-Shock Service Pressure, psi 150 Ser.	300 Ser.	400 Ser.	600 Ser.
Carbon Steel	A 105 or A 181	I & II	275	720	960	1440
	A 350	LF1				
Carbon Moly	A 182	F1	275	720	960	1440
	A 352	LC1				
304	A 182	F304	275	615	825	1235
316 & 347	A 182	F316 & F347	275	720	960	1440
3½ Ni	A 350	LF3	275	720	960	1440
Aluminum (see Notes 1 and 2)	B 247	M1A (3003-0)	40*	105*	135*	205*
		GS11A (6061-T6)	275*	720*	960*	1440*

1. Proposed aluminum flange ratings have been approved by ASA B 16 and are awaiting sponsor approval. If given final approval, these ratings will be published as an Appendix to ASA B 16.5.
2. *Proposed ratings for 6061-T6 are based on ASME Paper 56-PET-19 and are for welding neck flanges. The ratings of slip-on and socket-welding flanges are ⅔ of tabulated values since welding these types of flanges to pipe decreases their strength.

Castings . . . Aluminum valves are not specified even though valves with series 150 flanges are available and are less expensive than MSS austenitic valves with 150-lb flanges. The reasons for not specifying aluminum are: (1) The very low impact strength of aluminum valve castings (Charpy impact strength is of the order of 1-2 ft-lb; however, aluminum is not notch sensitive). (2) There are no standard ratings for aluminum valves (aluminum valves from two manufacturers were checked and although both valves were made of ASTM B 26 Alloy SG70A, the valve with the thicker flanges was rated at 100 psi and the other valve was rated at 175 psi). (3) Higher rated aluminum valves are not readily available or economical. Consequently, austenitic valves will generally be used in an aluminum piping system. This has been done quite successfully with only the minor problem of galvanic corrosion. The corrosion problem was not widespread and was quite simply solved by using flange and bolt insulators. (Table 9.)

Relative Cost . . . Table 11 shows the price advantage favoring the use of aluminum materials for low pressures. For pressures above the 150-lb class it is doubtful that the cost of aluminum would be less than Type 304 for all pipe sizes.

Although aluminum is less costly than Type 304 on a unit price basis, Type 304 has often been more economical for small low pressure installations because of the difficulty of obtaining small quantities of aluminum piping components. This problem, however, seems to be rapidly disappearing. A minor item not accounted for in the comparative cost data is the fact that aluminum piping requires more support.

Thermal conductivity is a property which requires con-

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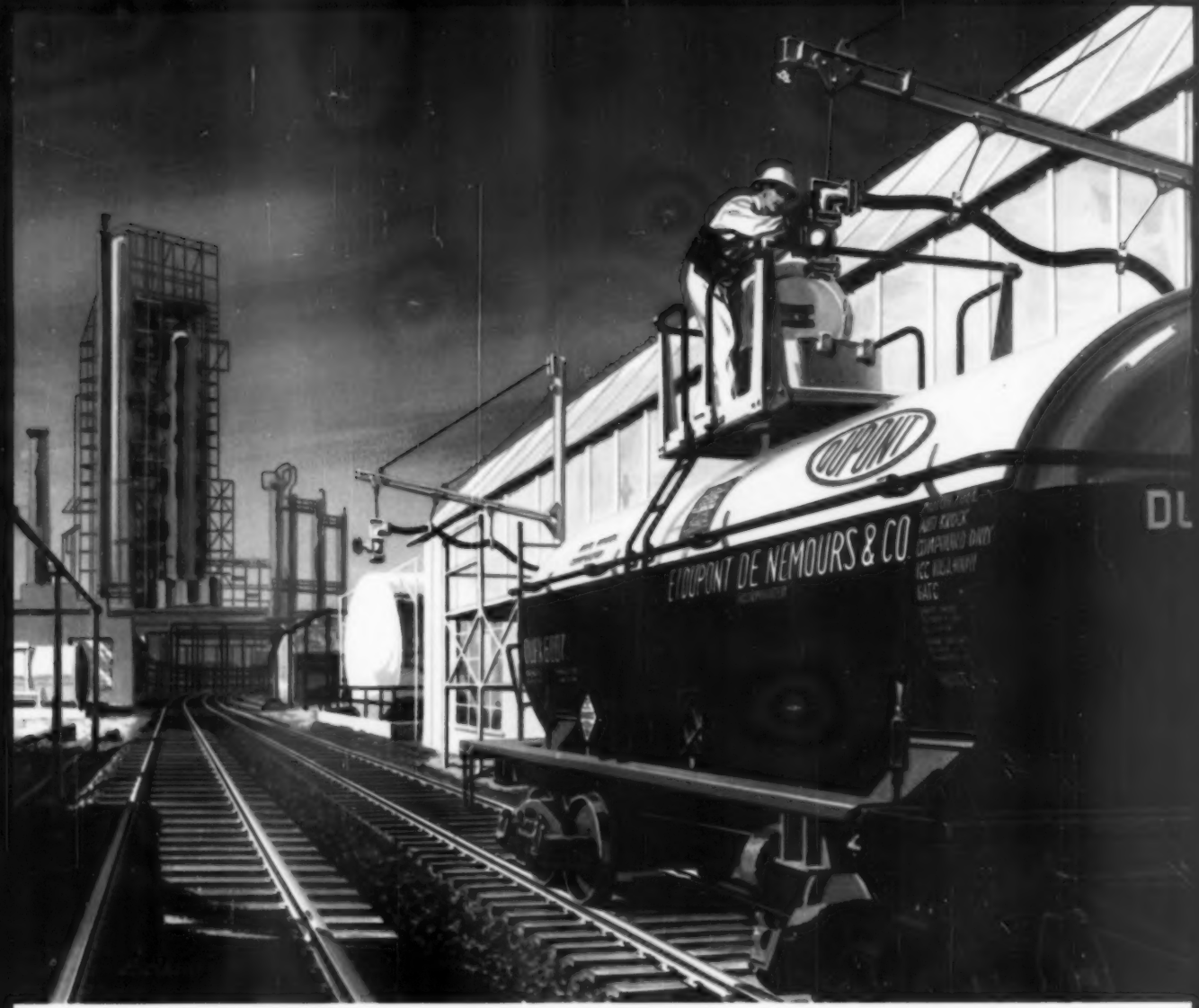

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sideration where heat leaks must be minimized. Austenitic stainless steels are much poorer conductors of heat than the non-ferrous materials and there might be situations in extremely low-temperature service where the lower cost of the non-ferrous materials would be offset by costs resulting from increased vaporization of the fluid.

Nickel and monel are two other non-ferrous materials which are acceptable for low temperature service. However, their cost is such that they would be uneconomical except where their corrosion resistant properties are needed. For example, monel pipe costs between 40 and 60 percent more than Type 304 pipe. (Table 7.) Nickel valves cost about 100 percent more than Type 304 valves, and cast monel valves cost about 75 percent more than 304 valves.

—150 F to —50 F

Normalized low carbon nickel steels have been widely used for this low temperature range because of the ability of nickel to effectively lower the transition temperature of normalized steels. The effect of increasing nickel on the low temperature keyhole notch Charpy impact properties of normalized steels is shown in Fig. 2.

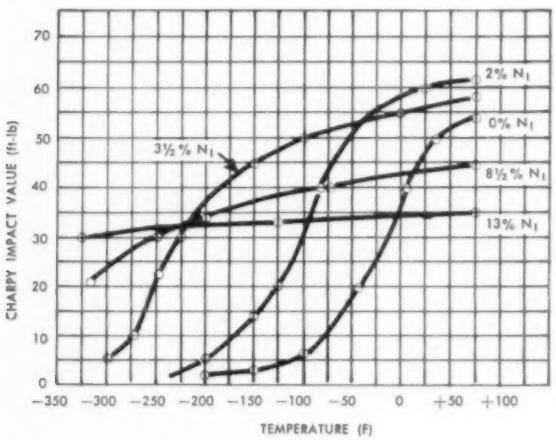

FIG. 2. Impact strength of nickel steel.

One of the nickel steels which is suitable for this temperature range is low carbon 5 percent nickel steel. 5 Ni pipe is available conforming to ASTM Specification A 333 Grade 5. This steel must be welded with an austenitic electrode of either 25-20 or 25-12 since there is no satisfactory ferritic electrode of matching composition currently available. Because of its cost, the fabrication problems, and the difficulty in obtaining components other than pipe, this material is not often used.

The more commonly used material for this temperature range has been low carbon 3½ percent nickel steel; however, as shown in Table 12 every suitable material except Type 304 Sch 40 is less expensive than 3½ percent Ni. Table 4 specifies a relatively new material, Cr-Cu-Ni steel, for the temperature range —150 F to —50 F. This steel is covered as Grade 4 in the ASTM low-temperature specifications. (Its chemical composition is: carbon 0.12 max., manganese 0.50 to 1.05, chromium 0.44 to 1.01, copper 0.40 to 0.75, nickel 0.47 to 0.98, aluminum 0.04 to 0.30, silicon 0.08 to 0.37, and sulfur and phosphorus 0.04 max.) The primary reason for using Cr-Cu-Ni steel is price. In addition, fabrication is simpler because it is easier to weld than 3½ Ni. Valves made of this steel are not available, but Type 304 MSS valves and 3½ Ni valves are available and suitable.

Earlier discussion as to whether aluminum should be used on process units in hydrocarbon service applies in this temperature range also. There still is an economic incentive for using aluminum in low pressure piping; however, it is not as great as it is for temperatures below —150 F.

TABLE 4. Ferrous Materials. —150 F to —50 F.

Bolting	ASTM A 320 Gr L7 (4140) bolts ASTM A 194 Gr 4 (C-Mo) nuts
Gasketing	Type 304 spiral-wound
Pipe	ASTM A 333 Gr 4 (Cr-Cu-Ni) ASA B 36.10
Butt-welding Fittings	ASTM A 420 Gr WPL4 (Cr-Cu-Ni)
Castings	ASTM A 351 CF8 (304) or CF8M (316) or ASTM A 352 Gr LC3 (3½% Ni)
Forgings	ASTM A 350 LF4 (Cr-Cu-Ni) Flanges to ASA B 16.5; S-W Fittings to ASA B 16.11

Discussion of Table 4

Bolting . . . The grades listed are the most economical of materials suitable for these temperatures. ASTM A 320 Gr L43 (4340) bolts are available, but considerably more expensive. (Table 6.)

Gasketing . . . Type 304 spiral-wound gaskets will give the most economical satisfactory flanged joint.

Pipe . . . Seamless Cr-Cu-Ni pipe is available in large quantities and costs slightly more than half the cost of 3½ Ni. (Table 7.) For small jobs, the designer will probably have to use 3½ Ni or lighter schedules of Type 304. Both Cr-Cu-Ni and 3½ Ni can be obtained in any ASA B 36.10 wall thickness if the minimum tonnage is ordered. (Table 7.)

Butt-welding Fittings . . . Cr-Cu-Ni butt-welding fittings cost the same as 3½ Ni.

Castings . . . 6 in. and smaller 150 lb MSS valves of Type 304 and 316 are less expensive than 150 lb 3½ Ni API 600 valves. In sizes 8-in. and above, valves should be of 3½ Ni. 3½ Ni valves should have 18-8 trim. It is not necessary to provide extended bonnets for valves in this temperature range because the economical insulation thickness is not so great as to cover the packing gland.

Forgings . . . 150 lb flanges of Cr-Cu-Ni cost the same as 3½ Ni. (Table 10.)

Relative Cost . . . Comparative costs (based on the piping configuration shown in Fig. 1) for the materials likely to be used in the temperature range of —150 F to —50 F are tabulated in Table 12.

Welding for —150 F to —50 F

According to our Welding Research people it has proved very difficult to obtain consistent impact properties in 3½ Ni weld deposits even with flux-coated electrodes for manual metallic arc. It is difficult to obtain a 3½ Ni weld having good impact properties with any electrode except in the flat position. The properties of the submerged-arc welds are even more erratic because of the lack of a suitable wire, even at —50 F, and as far as is known no one is using this procedure. Contrasted to this, Cr-Cu-Ni is relatively simple to weld. Piping fabricators' prices are an indication of the difficulties involved in welding 3½ Ni. Based on carbon steel = 1.0, the charges for 3½ Ni are approximately 2.5. For aluminum, aluminum-killed carbon steel, Type 304, and Cr-Cu-Ni steel the charges are approximately 2.0.

The Piping Code preheat temperatures for Cr-Cu-Ni and

3½ Ni are 175 F and 300 F, respectively. The Code postheat treatment temperatures are 1175 to 1350 F and 1100 to 1200 F for a minimum of one hour.

International Nickel Company investigators have reported that preheating as high as 600 F improves the low temperature impact properties of 3½ Ni weld metal. They also report that stress relief at 1100 F impairs the impact properties except with E8018C-2 electrodes. This is an apparent reversal of earlier data.[12] The experience of others does not confirm their later findings, however.[9]

The reader is also referred to a very comprehensive paper by Sagan and Campbell[13] on the factors which affect the notch toughness of low alloy welds.

—50 F to —20 F

In this temperature range, we find an area where we can have much controversy.

Following Piping Code requirements, piping materials for this temperature range as listed in Table 5 are recommended.

Discussion of Table 5

Bolting . . . A 193 Gr B7 bolts and A 194 Gr 2H nuts are suitable for temperatures down to at least —50 F. A few years ago the Piping Code was changed to eliminate the need for impact tests for these materials if they are quenched and tempered and if they are not to be used below —50 F.

Gasketing . . . Compressed asbestos sheet gaskets are specified for reasons of economy. Spiral-wound gaskets would probably be better, but are difficult to justify because good experience has been obtained with asbestos.

Pipe . . . A 333 Gr C pipe is specified because of its known good impact properties.

In private communications the author received tabulations of the results of impact tests performed at —50 F and —60 F on both as received and normalized A 106 Gr B pipe. In every case the normalized pipe passed the impact test. Apparently some selection was necessary to find the heats of A 106 pipe whose grain structure could be sufficiently refined by normalizing so that the pipe could be expected to have good impact properties after normalizing.*

Several published articles[14,15] plus these data lead to the conclusion that normalized A 106 pipe made from fully killed fine grain steel with .10 minimum silicon always has good impact properties down to —50 F and need not be tested.

Three-in. Sch 40 A 333 Gr C pipe costs 20 to 40 percent more than comparable A 106 pipe before normalizing; 8-in. Sch 40 A 333 Gr C pipe costs 40 to 90 percent more than comparable A 106 pipe. **The incentive for using normalized A 106 is apparent.**

There is disagreement as to what type of postheat treatment is needed for welds in normalized A 106 which is to be used down to —50 F. There are some that insist a normalizing heat treatment is needed. The Piping Code requires a stress relief at 1100 to 1200 F for all carbon steel which is to be used below —20 F. If this heat treatment is suitable for A 333 Gr C, it follows that it would be equally acceptable for normalized A 106.

There is another approach, to the question of whether impact tests are needed in this temperature range. The Unfired Pressure Vessel Code states that no impact test is required when the operating cycle is such that the pressure at —20 F is less than one-fifth of the maximum allowable working pressure at 100 F. The refrigeration people have a similar philosophy. Essentially this means that no impact

*Refer to "How to Obtain ASTM A 333 Gr C from A 106B and A 53B," M. Van Blaricom, this issue of *Petro/Chem Engineer*.

TABLE 5. —50 F to —20 F.

Bolting	ASTM A 193 Gr B7 bolts ASTM A 194 Gr 2H nuts
Gasketing	Compressed asbestos sheet
Pipe	ASTM A 333 Gr C, seamless
Butt-welding Fittings	ASTM A 420 Gr WPLC
Castings	ASTM A 352 Gr LCB
Forgings	ASTM A 350 Gr LF1 Flanges to ASA B 16.5; S-W Fittings to ASA B 16.11

TABLE 6. Bolting — Comparative Costs.

	BOLTS	NUTS	Comparative
Material	ASTM Spec. and Grade	ASTM Spec. and Grade	Cost[1] (Approximate)
AISI 4140	A193 B7	A194 2H	1.0
AISI 4140	A320 L7	A194 4	1.2[2]
AISI 4340	A320 L43	A194 4	2.05[2]
Type 304	A193 (or 320) B8	A194 8	6.5
Type 304	A193 (or 320) B8	B98 B-12	5.35
Type 347	A193 (or 320) B8C	A194 8C	7.6
Type 348	A193 (or 320) B8D	A194 8D	40.0 (Est.)
Type 321	A193 (or 320) B8T	A194 8T	6.95
Aluminum	B211 CG42A (2024-T4)	11ST-3	20.0

[1]Costs are based on each bolt being equipped with two nuts.
[2]There is an additional charge for impact tests which is not included.

TABLE 7. Pipe — Comparative Costs.

				Comparative Costs (Approximate)	
Material	ASTM Spec. and Grade	Type	Sch.	3 in.	8 in.
Carbon Steel	A53 A or B	Seamless	40	1.0	1.0
	A106 A or B	Seamless	40	1.10	1.10
	A333 C	Seamless	40	1.3 to 1.6	1.6 to 2.05[2]
3½ Ni	A333 3	Seamless	40	2.8 to 3.5	4.35 to 5.35[3]
Cr-Cu-Ni	A333 4	Seamless	40	1.65 to 1.85	2.6 to 2.9[3]
5 Ni	A333 5	Seamless	40	3.3 to 4.05	5.1 to 6.3[3]
9 Ni		Seamless	40	5.65 to 6.8	8.75 to 10.5[4]
Red Brass	B43	Seamless	Reg.	6.6	9.5[5]
			XS	10.1	14.9[5]
Copper	B42	Seamless	Reg.	7.6	9.5[5]
			XS	10.3	14.9[5]
Aluminum	B241 M1A(3003)	Seamless	40	1.7 to 1.9	1.9 to 2.1
			10	1.2	1.3
			5	.9	1.0
	B241 GS11A (6061-T6)	Seamless	40	2.0 to 2.25	2.3 to 2.6
			10	1.4	1.65
			5	1.1	1.2
Monel	B165	Seamless	40	15.8	17.6
304	A312 TP304	Seamless	40	10.1 to 10.7	12.9 to 13.6
		Seamless	10	6.0 to 6.35	—
		Seamless	5	4.6 to 4.85	—
		Welded & Annealed	10	5.25	—
			5	3.95	—
		Welded & Annealed[5]	40	10.3 to 10.9	12.3 to 12.9
			10	—	4.35 to 4.7
			5	—	3.5 to 3.8
304L	A312 TP304L		21% more than 304		
316	A312 TP316		64% more than 304		
316L	A312 TP316L		85% more than 304		
321	A312 TP321		18% more than 304		
347	A312 TP347		32% more than 304		

[1]Comparative costs are approximate. Comparative cost ranges indicate how price varies with the size of the order (from 20 tons to 5 tons).
[2]Small extra charge for impact tests.
[3]Minimum order 13 tons.
[4]Minimum order 11 tons.
[5]A312 except filler metal added.
[6]Based on 2000 lb or ft.

test is needed if the safety factor is 20 or greater, based on the ultimate tensile strength of the material at +100 F.

It has been proposed that the ASA B 31.3 Refinery Piping Code be revised along the same lines for temperatures down to —100 F. This approach is supported by evidence that a crack cannot be initiated or propagated if the stresses are below 6000 to 10,000 psi.[8,9] Assuming a steel with 50,000 psi UTS and using a safety factor of 20, stresses would be less than 2500 psi. Even assuming a stress concentration of three for sharp notches this puts the stress level only to 7500 psi.

Further justification of this approach lies in the fact that there are miles of plain carbon steel pipe operating below the transition temperature. (Below the transition temperature the impact strength of carbon steel becomes essentially constant for all temperatures.) These lines are just as susceptible to brittle failure as a carbon steel line operating down to —50 F on a process unit, yet there are very few recorded brittle failures in pipe.[6] It can be concluded from this that pipe is not nearly as likely to fail in a brittle manner as storage tanks. Why? Perhaps because the stress levels in carbon steel pipe operating below the transition temperature are almost always low, or perhaps because of the way pipe is made the metal generally has a finer grain than plate steels.

Several years ago a weld in an 8-in. line on one of our propane dewaxing plants failed in a brittle manner. The line had operated intermittently at temperatures between —40 F and ambient for about 21 years prior to the failure. The original weld, made with a gas torch, had less than 30 percent penetration in places. A reinforcement weld equal in thickness to 35 percent of the pipe wall was added later. There was no heat treatment of the weld. The normal pressure in this line was 40 psi. (The stress in the pipe due to pressure was no more than 610 psi when the pipe was new, or 950 psi after 0.10-in. corrosion.) The impact strength for the lap-welded pipe and the weld at —40 F was found to be 1.5 and 1.0 ft lb, respectively. At +80 F the average impact strength of the pipe was only 4.5 ft lb. The fact that other poor quality welds on this line operated for over 25 years without failure tends to prove the soundness of the approach of not to require impact tests where stresses are to be low. (Quality of welding is much better today than 25 years ago.)

There is, however, a lower temperature limit to this approach. At lower temperatures stresses due to thermal gradients and thermal shock become increasingly important. The following brittle failures illustrate this point.

There have been two failures of carbon steel pipe at our ammonia plant when it was exposed to liquid nitrogen. In the first failure the line split in several places. The cracks probably started in poor welds. The second case was a branch vent line which failed at the point it connected to the main vent header. It was believed possible that this part of the vent system could again have liquid nitrogen in it and consequently a stainless steel knockout drum was installed and the line up to the drum changed to stainless steel. The header is still carbon steel and although it is sometimes exposed to cold vapors, we have had no additional failures.

There was a similar failure on an ethylene plant. A vent, which was to be used only during start-up, from a —250 F pump was mistakenly left open. The result was that the bottom dropped out of 250 ft of the carbon steel drain header to which the vent was attached. The header failed first at the branch connections.

These are extreme cases. The first failure at our ammonia plant occurred in a 10-in. Sch 40 line operating at 300 psi at 30 F which was filled to a depth of 4-in. with liquid nitrogen. It was calculated that the theoretical stresses resulting from the temperature differential around the pipe would be of the order of 47,000-57,000 psi. Assuming a stress concentration factor of three for the notches at the poor welds, it is apparent that the tensile strength of the pipe at —300 F (120,000 to 140,000 psi) was exceeded.

Butt-welding Fittings and Forgings . . . The specified fittings and flanges are essentially the same price as regular carbon steel components. Most manufacturers will certify that these fittings and flanges will pass the 15 ft lb impact test; however, if you require it, they will conduct impact tests at a charge of about $50 per item on the order.

Castings . . . The Piping Code Committee recently re-examined the requirement that all carbon steel castings be impact tested if they are to be used between –20 F and –50 F. It had been suggested that ASTM A 216 Gr WCB carbon steel castings, if normalized, might be expected to have good impact properties down to –50 F and thereby permit elimi-

TABLE 8. Butt-Welding Fitt'ngs (ASA B 16.9) — Comparative Costs.

Material	ASTM Spec. and Grade	Sch.	Comparative Costs (Approx.) 3 in. Elbows	8 in. Elbows
Carbon Steel	A234 WPB	40	1.0	1.0
	A420 WPLC		1.4[1]	1.4[1]
3½ Ni	A420 WPL3	40	7.9[2]	6.75[2]
Cr-Cu-Ni	A420 WPL4	40	7.9[2]	6.75[2]
304	A403 WP304	40	6.4	7.6
	A403 WP304	10	3.65	4.3
	A403 WP304	5	3.15	3.45
	A352 CF8	40	14.6[2]	13.5[2]
316 and 347	A403 WP316 or 347	40	8.0	9.5
	A403 WP316 or 347	10	4.55	5.35
	A403 WP316 or 347	5	3.95	4.3
Aluminum	— M1A (3003F)	40	3.5	3.0
	— GS11A (6061-T6)	40	4.15	3.65

[1]Certified to meet impact requirements—additional charge for impact tests.
[2]Prices vary widely with quantity.

TABLE 9. Flanged Gate Valves — Comparative Costs.

Material	ASTM Spec. and Grade	Other Specifications	Series	Comparative Costs (Approximate) 3 in.	8 in.
Carbon Steel	A216 WCB	API 600	150	1.0	1.0
		API 600	300	1.45	1.5
	A352 LCB	API 600	150	1.15	1.15
		API 600	300	1.65	1.75
Carbon Moly	A352 LC1	API 600	150	1.15	1.15
		API 600	300	1.65	1.75
3½ Ni	A352 LC3	API 600	150	1.25	1.25
		API 600	300	1.8	1.9
304 or 316	A351 CF8 or	MSS SP-42 with	150	.87	1.25
	CF8M	ASA B16.5 Flanges	300	1.25	1.5
		Ditto with extended, bonnet	150	1.5	2.2
			300	2.2	2.7
		API 600	150	2.0 (Est.)	2.9 (Est.)
Brass	B62		150	0.57	0.88
Aluminum	B26 SG70A	MSS SP-42 Flanges	150	0.69	0.93

TABLE 10. Weld Neck Flanges — Comparative Costs.

Material	Series[1]	ASTM Spec. & Grade	3 in. RF WN Flgs.	8 in. RF WN Flgs.
Carbon Steel	150	A181 I or II	1.0	1.0
	300	A181 I or II	1.3	1.45
	150	A350 LF1	1.1	1.1
	300	A350 LF1	1.4	1.55
3½ Ni	150	A350 LF3	6.05	3.8
	300	A350 LF3	8.2	6.05
Cr-Cu-Ni	150	A350 LF4	6.05	3.8
	300	A350 LF4	8.2	6.05
304	150	A182 F304	5.3	5.65
316	150	A182 F316	6.9	7.3
Aluminum	150	B247 M1A (3003F)	3.3	3.0
		B247 GS11A (6061-T6)	3.3	3.0

[1]Flanges all have raised faces and conform to ASA B16.5 dimensions. (See Table 3 for a comparison of flange ratings.)

TABLE 11. Relative Piping Costs[1] for "Below −150 F." (Using Series 150 Flanges and Valves)

	304 Seamless[2]	304 Welded[3]	9 Ni Seamless[4]	Aluminum 3003 Seamless[5]	Aluminum 6061-TB Seamless[6]	Aluminum 6061-T6 Seamless[5]
Maximum Normal Operating Pressure	275	275	275	40	100[7]	275
3 in. Sch 40	3.3	3.2	2.65	1.7	1.8	1.9
10	2.6	2.45	—	1.65	1.7	1.75
5	2.35	2.2	—	1.6	1.65	1.75
8 in. Sch 40	4.35	4.25	3.9	1.95	2.05	2.25
10	—	2.8	—	1.85	1.95	—
5	—	2.6	—	1.8	—	—

[1]Costs are based on carbon steel = 1.0 and on the piping configuration shown in Fig. 1.

[2]Same as Table 1.

[3]Same as Table 1 except annealed electric fusion welded pipe.

[4]Same as Table 1 except 9 Ni seamless pipe.

[5]Same as Table 2.

[6]Same as Table 2 except aluminum (ASTM B26, alloy SG 70A) gate valves with series 150 flanges.

[7]Maximum normal operating pressure for 6061-T6 varies with the valve. There is no standard rating for aluminum valves.

TABLE 12. Relative Piping Costs for "−150 F to −50 F." (Using Series 150 Flanges)

	Cr-Cu-Ni Seamless	3½ Ni Seamless	304 Seamless[6]	304 Welded[7]	Aluminum 3003 Seamless[9]	Aluminum 6061-T6 Seamless[9]	Aluminum 6061-T6 Seamless[5]
Maximum Normal Operating Pressure	275	275	275	275	40	100[10]	275
3 in. Sch 40	1.55[2]	2.05[3]	2.8	2.7	1.2	1.3	1.4
10	—	—	2.1	2.0	1.15	1.2	1.3
5	—	—	1.9	1.75	1.1	1.1	1.25
8 in. Sch 40	1.9[4]	2.25[5]	3.7	3.6	1.35	1.45	1.7
10	—	—	—	2.2	1.25	1.35	1.55
5	—	—	—	2.0	1.2	1.25	1.5

[1]Costs are based on carbon steel = 1.0 and on the piping configuration in Fig. 1.

[2]Same as Table 4 — MSS type 304 valves (with ASA B16.5 flanges).

[3]Same as Table 4 — 3½ Ni valves. For sizes 6 in. and larger in the temperature range −75 F to −50 F the cost factor can be reduced by using carbon moly valves (A352 LC1), e.g., 8-in. sch 40 factor = 1.8.

[4]In 6 in and smaller sizes cost can be reduced by using type 304 valves (with ASA B16.5 flanges) instead of 3½ Ni valves, e.g., 3-in. sch 40 factor = 1.8.

[5]For temperature range of −75 F to −50 F the cost can be reduced by using carbon moly (A352 LC1) valves, e.g., 8 in sch 40 factor = 2.2.

[6]Same as Table 1 except valves do not have extended bonnets.

[7]Same as Table 1 except pipe is annealed electric fusion welded and except valves do not have extended bonnets.

[8]Same as Table 2 except valves do not have extended bonnets.

[9]Same as Table 2 except aluminum (ASTM B26, alloy SG 70A) gate valves with series 150 flanges and conventional bonnets.

[10]Maxmium normal operating pressure for 6061-T6 varies with the valve. There is no standard rating for aluminum valves.

nation of the Code-required impact test. The data assembled by the Committee indicated that the impact test requirements should beretained. Only if carbon steel castings are made from basic electric furnace steel and given a special water quenching heat treatment do they have good chance of meeting the 15 ft lb test at −50 F.

Carbon steel valves for this temperature range should have 18-8 trim. In the smaller sizes Type 304 MSS gate valves with ASA B 16.5 flanges are cheaper and are recommended.

Relative Cost . . . The cost factor for low temperature carbon steel is 1.3 for both the 3-in. and 8-in. sizes. This factor is based on using low-temperature carbon steel valves (A 352 Gr LCB). In sizes 4-in. and smaller MSS Type 304 valves are less expensive and if used, the factor can be reduced, e.g., 3-in. factor = 1.1. The comparative costs for other low-temperature piping materials are listed in Tables 11 and 12 and as can be seen from the tables there generally is no economic incentive to use any of them between −50 F and − 20 F.

The author is very grateful for the generous assistance given by many people from both the Standard Oil Company (Indiana) and other companies.

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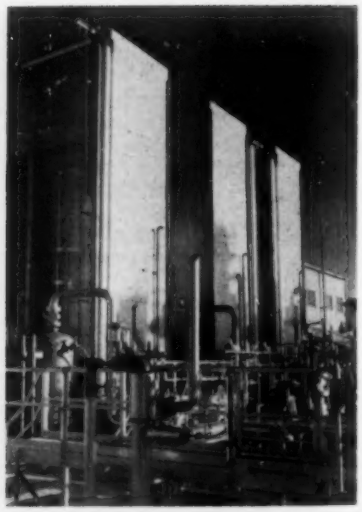
construction briefs . . .



▸ **The U. S. Congress** is considering a program to build 12 additional plants to extract helium — needed in defense and space activities — from natural gas before the gas moves on through pipelines to consumers. Plants would be built by private industry, if possible, with the government buying the helium and storing it in the Cliffside gas field, near Amarillo, Texas, against future needs. Pictured is the helium purification facility operated by the Bureau of Mines at Keyes, Oklahoma, built by Air Products, Inc.

▸ **Shell Oil Co.** will build a natural gasoline and propane recovery plant at the mouth of the Mississippi River to extract an estimated 725 bbl of natural gasoline and 400 bbl of propane daily which at present is not recovered from gas produced in Shell's Southwest Pass (Louisiana) Block 24 and 27 oil fields. The unit will use a process of low refrigeration and absorption.

It's New

WORLD-WIDE NEW EQUIPMENT GUIDE COMING JULY 15

PETRO/CHEM EQUIPMENT

The regular monthly NEW EQUIPMENT and NEW LITERATURE pages are omitted from this issue only. These popular features appear again in the August issue. Meanwhile, watch for the WORLD-WIDE NEW EQUIPMENT GUIDE, the latest and most complete reference manual of petroleum industry equipment, services, and products from around the world.

▸ **Davis field gasoline plant** of Upton County, Texas, to go into operation this month, will have an initial throughput of some 3 MMcf of gas per day. It will utilize casinghead gas from the Davis field, 28 miles southeast of Odessa, to produce propane, butane, and natural gasoline. This is the first plant to be built by Mesquite Gas Products, Inc., Midland, a new firm organized for constructing, owning, and operating small gasoline plants in the Permian Basin.

▸ **Signal Oil and Gas Co.** will rebuild the former Hancock Oil Co. refinery on Signal Hill near Long Beach, California, which was partially destroyed by fire two years ago. Rebuilt refinery will have capacity of 15,000 to 20,000 bbl per day by end of 1960. Sole product will be gasoline.

▸ **Sun Oil Co.** will build an $8,000,000 plant to produce refined-grade petroleum naphthalene at the Toledo, Ohio, refinery. With capacity of 100,000,000 lb per year, this will be largest petroleum naphthalene plant in the world.

▸ **Ashland Oil and Refining Co.,** Ashland, Kentucky, has awarded contract to Badger Manufacturing Co., Cambridge, Massachusetts, for erection of a hydrodealkylation unit at the company's No. 1 refinery at Catlettsburg, Kentucky. Plant will produce 75,000,000 lb per year of naphthalene and 15,000,000 gal per year of benzene.

▸ **Multi-million dollar expansion** of the Husky Hi-Power refinery at Cody, Wyoming, will increase output capacity to approximately 15,000 bbl a day.

. . . *petroleum chemicals*

▸ **New multi-million dollar plant** to be built near Beaumont, Texas, by Goodyear Tire & Rubber Co. will produce two new synthetic rubbers — Natsyn, made from isoprene, and Budene, made from butadiene — both petroleum derivatives.

▸ **Borden Co. and United States Rubber Co.** have formed a jointly-owned chemical company to be called Monochem, Inc., to construct a $50,000,000 complex of chemical plants to convert hydrocarbons into more than a dozen chemical products. Present plans call for both companies to erect adjacent individually owned plants which will use the Monochem plant's output for manufacture of other chemical products.

▸ **Union Carbide Caribe** will build the world's largest polyethylene plant — to produce 110,000,000 lb per year — near Ponce, Puerto Rico. Plant will be adjacent to the company's ethylene oxide-glycol plant which operates on ethylene from by-product gas streams of the nearby Commonwealth Oil refinery.

▸ **Humble Oil & Refining Co.** will increase capacity for production of butyl rubber at its Baytown, Texas, refinery from 125,000,000 lb per year to more than 170,000,000 by the second quarter of 1961.

▸ **Petro-Tex Chemical Corp.,** Houston, jointly owned by Tennessee Gas Transmission Co. and Food Machinery & Chemical Corp., will build a multi-million dollar plant to produce 30,000,000 lb of maleic anhydride annually by a new process. Engineering and design is by Scientific Design Co., New York.

▸ **M. W. Kellogg** will design and construct Solar Nitrogen Chemicals' 300 ton per stream day ammonia plant near Joplin, Missouri.

▸ **Oronite Chemical Co.** will spend $3,400,000 to more than double its capacity to produce polybutene. Oronite, a subsidiary of Standard of California, will build a new polybutene unit and expand two existing plants at the Richmond refinery.

▸ **California Chemical Co.,** subsidiary of Standard Oil Co. of California, will more than double its capacity to produce polybutene with construction of a new unit and expansion of two existing plants at its Richmond refinery.

▸ **Badger Manufacturing Co.,** Cambridge, Massachusetts, has contract for design, engineering, and construction of the new Sinclair-Koppers Chemical Co. styrene monomer plant at Pasadena, Texas.

Houston Chemical Corp. will become the third U. S. producer of tetraethyl lead and tetramethyl lead with construction of plants at Beaumont, Texas, adjacent to Mobil Oil Co.'s refinery. Also to be built is a plant to produce ethylene oxide and its derivatives from ethylene from Mobil's new plant now under construction.

Tennessee Oil Refining Co., division of Tennessee Gas Transmission Co., will enter the petroleum chemicals field with completion of a 2000-bbl per day unit for production of aromatic solvents at its Chalmette, Louisiana, oil refinery. Work on the project will begin this summer.

Shell Chemical will triple its projected plant capacity for production of polyisoprene with construction of a plant in the Midwest to produce 80,000,000 lb per year and expansion of the Torrance, California, plant to 40,000,000 lb per year level.

. . . onstream

A combination UOP Unifining-Platforming unit has gone onstream at the Ruhrchemie AG refinery at Oberhausen-Holten, Germany. In addition to pretreating 2000 bbl per std day of naphtha for Platformer feed, the Unifining unit treats 900 bbl per std day of light gasoline.

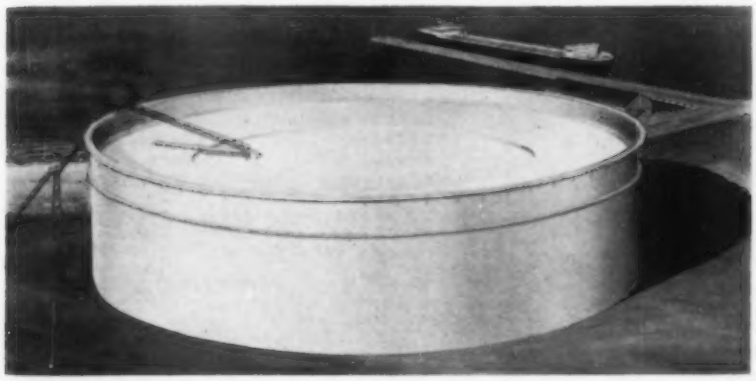
Maljamar gas products plant in Eddy County, New Mexico, jointly owned by Skelly and Sinclair, is now onstream. Plant has a design capacity of 30 MMcf per day and an installed compressor capacity of 15 MMcf. Initial liquid production of 60,000 gal per day will include propane, butane, and natural gasoline.

A $30,000,000 synthetic rubber plant designed by Blaw-Knox Co., Chemical Plants division, Pittsburgh, has been dedicated at the Yokkaichi, Japan, installation of Japan Synthetic Rubber Co., Ltd.

BP Group's first refinery in North America — at Ville d'Anjou, 10 miles east of Montreal, Canada — is constructionally complete and is due to go onstream at an early date. The plant, with capacity of 25,000 bbl a day, is designed to produce a high yield of high octane motor gasoline together with kerosine, diesel oil, furnace oils, and heavy fuel oil. LPG will also be produced and refinery waste gases sold for petroleum chemical production.

New hydrofluoric acid alkylation unit with capacity of 1500 bbl per day of butylene alkylate has gone onstream at the Santa Fe Springs, California, refinery of Wilshire Oil Co.

A 100,000 bbl a day topping plant addition to Texaco's refinery in Trinidad is now onstream, making the company's complex on the island one of the largest in the world. Rated capacity of the entire refinery is now 235,000 bbl daily.



Field construction of the world's largest crude oil storage tank has been started in Kuwait by the British subsidiary of Chicago Bridge & Iron Co., Chicago. The giant steel tank, 260 ft in diameter and 64 ft high, is being built for American Independent Oil Co. in Mena Abdulla, on the Arabian Gulf. It will have a capacity of 605,000 bbl — more than enough oil to fill an 85,000-ton ocean tanker or to supply a 20,000-bbl per day refinery for a month.

. . . international scene

British American Oil Co., Ltd., has awarded contract worth approximately $400,000 to the Fluor Corp. of Canada, Ltd., for engineering, purchasing, and construction of a 3500 bbl per day naphtha hydrodesulfurization unit at the Calgary, Alberta, refinery. Unit will remove sulfur compounds from naphtha by catalytic action.

B-A will build a marine terminal near Point Tupper, on Strait of Canso, Nova Scotia, as first step in long-range plans for development of the property as site for manufacture and distribution of petroleum products.

Shell Oil Co. of Canada, Ltd., will build a $3,000,000 distillate hydrodesulfurizer at its Montreal refinery, with completion scheduled for December of this year.

M. W. Kellogg has principal construction contract for the $26,600,000 Istanbul refinery to be owned and operated by California Texas Oil Corp. and Turkiye Petroleri A. O., Turkish Government-owned company through a jointly owned firm called Istanbul Petrole Rafinerisi, AS.

Imperial Oil Ltd. has announced a million dollar construction project at its Sarnia, Ontario, Canada, refinery involving installation of equipment for treatment of furnace fuel oil. The hydrofiner unit will have output of some 32,000 bbl per day.

A company, Petroleos de Galicia, SA, has been formed in Spain to construct a 26,000 bbl a day, $15,000,000 refinery in Vigo Bay.

Newfoundland's first petroleum refinery, a 5000 bbl per day refinery at St. John's, will be built as a cooperative project by the provincial government and Golden Eagle Refining Co. of Canada, Ltd., a newly formed wholly owned subsidiary of Ultramar Co., Ltd.

The Morocco Government plans an oil refinery at Mohammedia to include a topping plant of 1,250,000 metric tons, a catalytic plant of platforming type, a desulfurization unit with capacity of 230,000 metric tons, and storage capacity of 180,000 cu meters.

The Indian Oil and Natural Gas Commission will install pilot plant to refine crude from test wells in Cambay and Ankleshwar regions.

Syria's General Petroleum Authority plans a 30,000,000 lb ($8,000,000 free rate) refinery in Latakia.

Part 2 of How to Design . . .

safe flare stacks

J. D. HAJEK
Process Engineer

E. E. LUDWIG
Manager, Process Engineering

The Dow Chemical Company, Freeport, Texas

Blowout

The upper limit of stability of a flame is blowout, which is simply its extinction at a high critical velocity. This parameter determines the upper limit of stability for a flame in still air using no pilots. Blowout results from the combined effects of dilution with outside air at high velocities and cooling resulting from the dilution.

A mixture with a fuel concentration just above the lower limits of inflammability requires less dilution with outside air to approach the lower limit than a rich fuel and thus blows out a lower velocity. A pure fuel has the highest blowout velocity for a given system.

No correlation has been developed to date to predict blowout because of a lack of data. However, one major manufacturer for example, states their pilots permit blowout velocities of 400 ft per sec or more. This is well above normal stack velocities. Normally fuels with low heating values as low as 115 Btu per cu ft can be flared successfully if an adequate number of properly located pilots are used.

Limits of Inflammability

Data for a large number of fuel-air systems and a smaller number of fuel-oxygen systems[9] are presented.

Because of the scarcity of data on limits of inflammability for fuel-oxygen systems, an attempt was made to develop a correlation relating limits in air to limits in oxygen.

A correlation with an unusually high accuracy is presented in Fig. 10 which was found to be good for saturated and unsaturated hydrocarbons, hydrogen, carbon monoxide, and ammonia. All available data is presented. This can be extended to oxygen-nitrogen systems for all oxygen concentrations. (See Fig. 11 and 12 for example problem.)

Limits may be calculated for mixtures by knowing the limits of each component for the same air or oxygen system. This method, which is described in *Chemical Engineers' Handbook*, Third Edition, has been found to be inaccurate for the upper limit of some systems.

Caution should be used when flaring acetylene as the upper limit of inflammability is increased rapidly for tube diameters above 5 cm. For most systems this is usually not the case. Tube length may also affect the results.

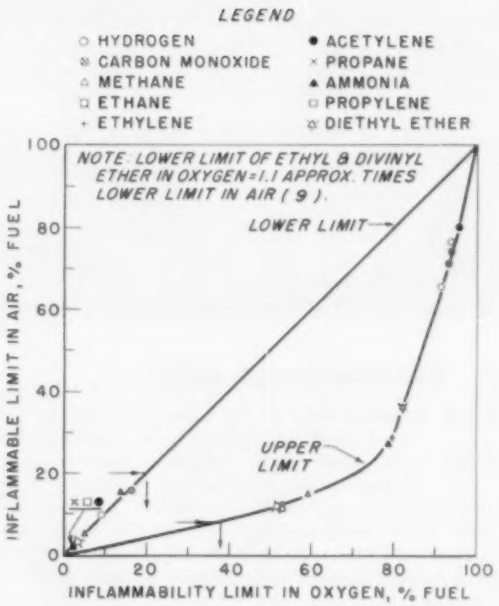


FIG. 10. Inflammability limits air and oxygen systems.

Heat Damage to Area From Flame Radiation

A major manufacturer[14] presented a method to determine the distance a stack should be from structures and personnel to prevent heat damage by radiation. The distance used is

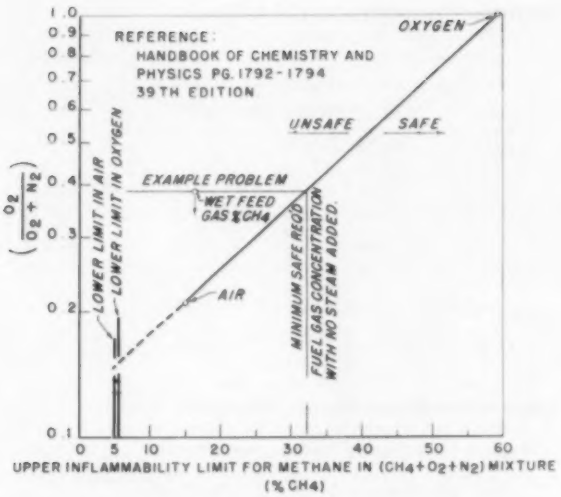


FIG. 11. Upper inflammability limits CH_4—O_2—N_2 system.

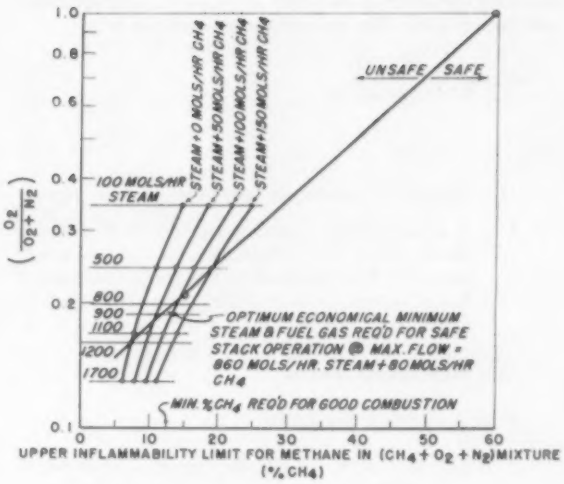

UNSAFE
SAFE
STEAM +0 MOLS/HR CH4
STEAM +50 MOLS/HR CH4
STEAM +100 MOLS/HR CH4
STEAM +150 MOLS/HR CH4
100 MOLS/HR STEAM
500
800
900
1100
1200
1700
OPTIMUM ECONOMICAL MINIMUM STEAM & FUEL GAS REQ'D FOR SAFE STACK OPERATION @ MAX. FLOW = 860 MOLS/HR. STEAM + 80 MOLS/HR CH4
MIN. % CH4 REQ'D FOR GOOD COMBUSTION
O2 / (O2 + N2)
UPPER INFLAMMABILITY LIMIT FOR METHANE IN (CH4 + O2 + N2) MIXTURE (% CH4)

FIG. 12. Determination of minimum safe corrective data for stack operation CH_4—O_2—N_2 system.

TABLE 1.*

Tube Diameter = 1.000 in. glass tube
U_f = Fundamental Burning Velocity = that velocity normal to any tangent to the flame surface

Fuel	% Fuel at Maximum Velocity	(Air System) Maximum Fundamental Burning Velocity, U_f, Cm/Sec at 298°K
Methane	9.96	33.8
Ethane	6.28	40.1
Propane	4.54	39.0
Butane	3.52	37.9
Pentane	2.92	38.5
Hexane	2.51	38.5
Heptane	2.26	38.6
2-Methyl Propane	3.48	34.9
2,2-Dimethylpropane	2.85	33.3
2-Methylbutane	2.89	36.6
2,2-Dimethylbutane	2.43	35.7
2,3-Dimethylbutane	2.45	36.3
2,2,3-Trimethylbutane	2.15	35.9
2-Methylpentane	2.46	36.8
3-Methylpentane	2.48	36.7
2,3-Dimethylpentane	2.22	36.5
2,4-Dimethylpentane	2.17	35.7
Ethene	7.40	68.3
Propene	5.04	43.8
1-Butene	3.87	43.2
1-Pentene	3.07	42.6
1-Hexene	2.67	42.1
2-Methyl-1-Propene	3.83	37.5
2-Methyl-1-Butene	3.12	39.0
3-Methyl-1-Butene	3.11	41.5
2-Ethyl-1-Butene	2.65	39.3
2-Methyl-1-Pentene	2.80	39.6
4-Methyl-1-Pentene	2.62	40.5
Propyne	5.86	69.9
1-Butyne	4.36	58.1
1-Pentyne	3.51	52.9
1-Hexyne	2.97	48.5
4-Methyl-1-Pentyne	2.87	45.0
2-Butyne	4.36	51.5
3-Hexyne	3.05	45.4
Cyclohexane	2.65	38.7
Benzene	3.34	40.7

*Gerstein, O. L. and E. L. Wong, Jour. Amer. Chem. Soc. *73*, Jan. p 418-422 (1951).

TABLE 2.*

Fuel	Fraction of Stoichiometric ϕ	(Air System) Maximum Fundamental Burning Velocity, U_f, Cm/Sec at 298°K
Propadiene	1.21	73.8
2-Methylpropane	1.10	34.9
1-Deutero-2-Methylpropane	1.10	33.4
2-Deutero-2-Methylpropane	1.10	33.4
1-Butene-3-yne	1.09	75.5
2,3-Dimethyl-1-Butene	1.31	39.2
2,3-Dimethyl-2-Butene	1.15	37.2
2-Pentene	1.24	43.1
2-Pentyne	1.15	51.3
4-Methyl-2-Pentyne	1.25	45.6
2-Methyl-1, 3-Pentadiene	1.15	39.0
Methylcyclopropane	1.16	49.2
Ethylcyclopropane	1.25	47.5
Cis-1, 2-Dimethylcyclopropane	1.16	46.5
Trans-1,2-Dimethylcyclopropane	1.18	46.2
1,1,2-Trimethylcyclopropane	1.15	43.5
2-Cyclopropyl-1-Butene	1.15	42.5
Cyclobutane	1.15	56.6
Ethylcyclobutane	1.15	44.7
Isopropylcyclobutane	1.35	39.1
N-Decane	1.05	40.2
1-Decene	1.12	41.2
Hexadecane	1.08	40.7
Benzene	1.08	44.6
Toluene	1.05	38.8
O-Xylene	1.08	34.4
1,2,4-Trimethylbenzene	1.09	34.3
N-Butylbenzene	1.08	35.9
t-Butylbenzene	1.05	36.6
Diphenylmethane	1.07	33.2
Tetralin	1.01	36.2
Trans-Decalin	1.09	33.9
Dimethyl Ether	1.19	45.6
Diethyl Ether	1.15	39.9
Ethylene Oxide	1.25	91.3
1,2-Propylene Oxide	1.28	69.7
Propionaldehyde	1.31	49.0
Acetone	1.31	45.5
Acrylonitrile	1.05	47.0
Isopropylamine	1.14	26.7

*Wagner, P. and G. L. Dugger, Jour. Amer. Chem. Soc. 77, p 227-231 (1955).

that from the flame to the object in question. Distance varies with heat release. The recommended equation is:

$$D = \sqrt{\frac{(F)\ (Q)}{(4)\ (3.14)\ (K)}}$$

Where:

D = Minimum distance in feet from flame to object

F = A dimensionless constant equal to 0.20 for methane which has a hydrogen to carbon *weight* ratio of 0.333 and equal to 0.33 for propane which has a weight ratio of 0.222. Use 0.40 when in doubt to be safe.

Q = Heat release, Btu/hr

K = A constant, Btu/hr-ft²

(a) K = 1000 for objects exposed 20 minutes or more

(b) K = 1500 for objects exposed less than 20 minutes

The above equation is useful in determining multiple stack spacing, stack height, and distances of the flame from personnel, buildings, railroad ties, and uninsulated product transfer lines.

EXAMPLE PROBLEM

Basis:

Design a flare stack to safely dispose of the following gas mixture by burning. Flow will vary from 0 to 250,000 scfh maximum and will enter the stack at 167 F saturated with water vapor. The flame is to be smokeless.

Dry Gas		
Comp.	Mol %	
CH_4	25.0	
O_2	50.0	(Maximum)
N_2	25.0	
	100.0	

Determine Water of Saturation:

$$\text{Mols/hr dry gas} = \left(\frac{250{,}000}{379}\right) = 659.0 \text{ mols/hr}$$

Vapor pressure water @ 167 F = 5.590 psia

Let x = mols/hr of water vapor

Assume a water seal pot ahead of the stack. The maximum recommended pressure drop for one manufacturer's smokeless flare 16 ft long burner sections is 0.5 psi (1.5 psi where smoke is not objectionable). The stack drop is usually about equal to the burner Δ P. Assume 1.0 psig in water seal pot to get saturation pressure.

$$\left(\frac{659.0 + x}{14.7 + 1.0}\right) = \frac{x}{5.590}$$

x = 365 mols/hr of equilibrium water vapor

Determine Composition of Gas to Stack:

Comp.	Mols/Hr	Y Mol Fr.	MW	W = (Y) (MW)	167 F Viscosity Cent.	(W) (Visc.)
CH_4	164.75	0.1609	16	2.57	0.0122	0.0315
O_2	329.50	0.3218	32	10.30	0.0227	0.2337
N_2	164.75	0.1609	28	4.51	0.0195	0.0880
H_2O Vap.	365.00	0.3564	18	6.42	0.0115	0.0739
	1,024.00	1.0000		23.80		0.4271

Avg. MW = 23.80

$$\text{Avg. Viscosity} = \left(\frac{0.4271}{23.80}\right) = 0.0177 \text{ Centipoise}$$

Approximate Burner Section Diameter:

Assume 0.4 psi across 16 ft burner section:

Avg. pressure = 14.7 + 0.2 = 14.9 psia

$$\text{Gas density @ 167 F} = \frac{(23.8)\ (14.9)\ (520)}{(379)\ (14.7)\ (627)} =$$

0.0528 lb/cu ft at 14.9 psia

Viscosity was previously determined to be 0.0177 centipoise. Check ΔP: Use Crane Technical Paper No. 410

lb/hr = (1,024 mols/hr) (23.8) = 24,400 lb/hr

Assume 12-in. stack (¼-in. wall)

x-section = 0.8185 sq ft

$$Re = \frac{(6.31)\ (24{,}400)}{(12.25)\ (0.0177)} = 710{,}000$$

f = 0.0146

The manufacturer's burners as mentioned under *"Determine water of saturation"* above are equivalent to 190 ft of pipe.

$$\Delta P = \frac{(0.000336)\ (0.0146)\ (24{,}400)^2 (1.90)}{(275{,}855)\ (0.0528)} = 0.381 \text{ psi}$$

$$\text{Max. Avg. Velocity} = (24{,}400) + (3{,}600)\ (0.0528)\ (0.8185) = 157 \text{ ft/sec}$$

Δ P does not exceed 0.5 psi allowable so we are o.k. Use a 12-in. burner.

Stack diameter will depend on the allowable system pressure drop.

The stack diameter should be equal to or greater than the burner section.

Draw a Flash Back Diagram for this System:

This diagram will show where we are with respect to the danger of flash back which can lead to detonation and destruction.

Flash back velocity for a given composition varies with stack diameter and gas temperature when the combustible content is between the upper and lower limits of inflammability.

It is convenient to base the diagram on a 12-in. ID stack and a feed temperature of 25 C. Factors can correct for

other diameters and temperatures as necessary. Almost all data are reported at 25 C and must be corrected for other temperatures.

Fortunately, data for this system are available.[7] For systems on which no data are reported use of Fig. 6 is suggested. This latter correlation is good only for fuel-oxygen mixtures, but can be extended to fuel-air mixtures and intermediate fuel-oxygen-enriched air mixtures. Fig. 6 is not complete.

The basic equation as discussed under **Flash Back** is as follows:

$$(U_F)_T = 0.2015\ (g_L)\ (D)$$

Water vapor acts as inert nitrogen as discussed in the text.

To get a complete picture of the methane-enriched air system, one must plot a series of flash back envelopes for various oxygen concentrations rather than only one as shown in Fig. 1.

The diameter, D, we have set at 1.0 ft for now and the values of $(g_F)_L$ we can get.[7]

Values of $(g_F)_L$ are reported[7] for $(O_2)/(O_2 + N_2)$ ratios of 0.21 (air), 0.35, 0.50, 0.667, and 1.00 (pure oxygen).

But we have (in addition to fuel) O_2, N_2, and water vapor. Since water vapor acts as nitrogen, we can assume the mols of water vapor + N_2 are equal to mols of N_2.

The percent fuel range one must consider is the lower limit in air to the upper limit in oxygen. This is 5 to 60 percent fuel.

Refer to Reference 7 to get $(g_F)_L$, the experimental factor.

Data is presented as g_F versus fraction of stoichiometric. Fraction of stoichiometric is simply the percent fuel in the mixture in question divided by the percent fuel in a stoichiometric mixture.

$$\text{For } (O_2)/(O_2 + N_2) = \frac{50}{50 + 25} = 0.667$$

$$\frac{O_2}{O_2 + N_2 + H_2O} = \left(\frac{329.50}{329.50 + 164.75 + 365.00}\right) = \left(\frac{329.5}{859.25}\right) = 0.384$$

% Fuel = 16.09% for gas composition (wet) to stack

% Fuel at stoichiometric:

$N_2 + H_2O$ is considered = N_2 (both inert)

$$\frac{N_2 + H_2O}{O_2} = \frac{164.75 + 365.00}{329.50} = \frac{529.75}{329.50} = 1.607$$

$$\frac{O_2}{CH_4} = \frac{329.50}{164.75} = 2.00$$

Therefore:

$CH_4 + 2O_2 + (2)\ (1.607)\ N_2 \rightarrow$ Combustion products

$(CH_4) + (2O_2) + (3.214\ N_2) \rightarrow$ Combustion products

Now balance the equation:

$$(CH_4) + (2O_2) + (3.214\ N_2) \rightarrow CO_2 + 2H_2O + 3.214\ N_2$$

$$\%\ \text{Fuel (@ stoich.} = \frac{(1)\ (100)}{(1 + 2 + 3.214)} = \left(\frac{100}{6.214}\right) = 16.09\%\ \text{Fuel}$$

Therefore:

$$\text{Fraction of stoich.} = \frac{16.09}{16.09} = 1.00\ \text{(coincidence)}$$

From Reference 7 interpolating between the 0.35 and 0.50 parameter at 16.09% fuel for $\frac{O_2}{O_2 + N_2 + H_2O} = 0.384$, a value of about 4000 for $(g_F)_L$ is obtained.

Flash back velocity is = $(0.2015)\ (g_L)\ (D) = (0.2015)\ (4000)\ (1.0) = 806$ ft/sec

Thus it is obvious that the flame will flash back even at full flow of gas, since the actual gas velocity is lower.

The gas composition must be changed. There are two possibilities:

1. Add sufficient fuel gas (CH_4) to the base of the stack until the fuel concentration is above the upper limit of inflammability for the feed gas

   $(O_2)/(O_2 + N_2 + H_2O)$ ratio.

2. Add nitrogen or steam to the base of the stack to drop the $(O_2)/(O_2 + N_2 + H_2O)$ ratio.

First plot % fuel at upper limit of inflammability versus $(O_2)/(O_2 + N_2)$ ratio. This is shown on Fig. 11.

In the absence of better data it is reasonable to assume the plot in this section is reliable, since it checks the limits calculated from reference 7 and is slightly on the safe side for all values of $(O_2)/(O_2 + N_2)$. It is significant that the line of limits from the reference is exactly parallel to the line shown.

Determine Fuel Gas Addition to Exceed Upper Limit:

% Fuel in wet gas = 16.09% and the $(O_2)/(O_2 + N_2)$ ratio is 0.384

For the 0.384 value, Fig. 11 shows the % fuel must exceed 32.25 percent.

Use 35 percent to be safe.

Remember in using $(O_2)/(O_2 + N_2)$ that H_2O was considered as N_2, as discussed before (H_2O acts as H_2).

Mols/hr of total wet feed = 1,024.00

CH_4 = 164.75

all but CH_4 = 859.25

$$\text{Total } CH_4 = \left(\frac{859.25}{1\text{-}0.35}\right) - 859.25 = 462.67\ \text{mols/hr}$$

CH_4 to be added = 462.67 − 164.75 = 297.92 mols/hr

Scfd = (297.92) (24) (379) = 2,710,000 Scfd

$$\$/\text{day (@ 18¢/1,000 Scf} = \frac{(2{,}710{,}000)\ (\$0.18)}{(1{,}000)}$$

= 487 $/day

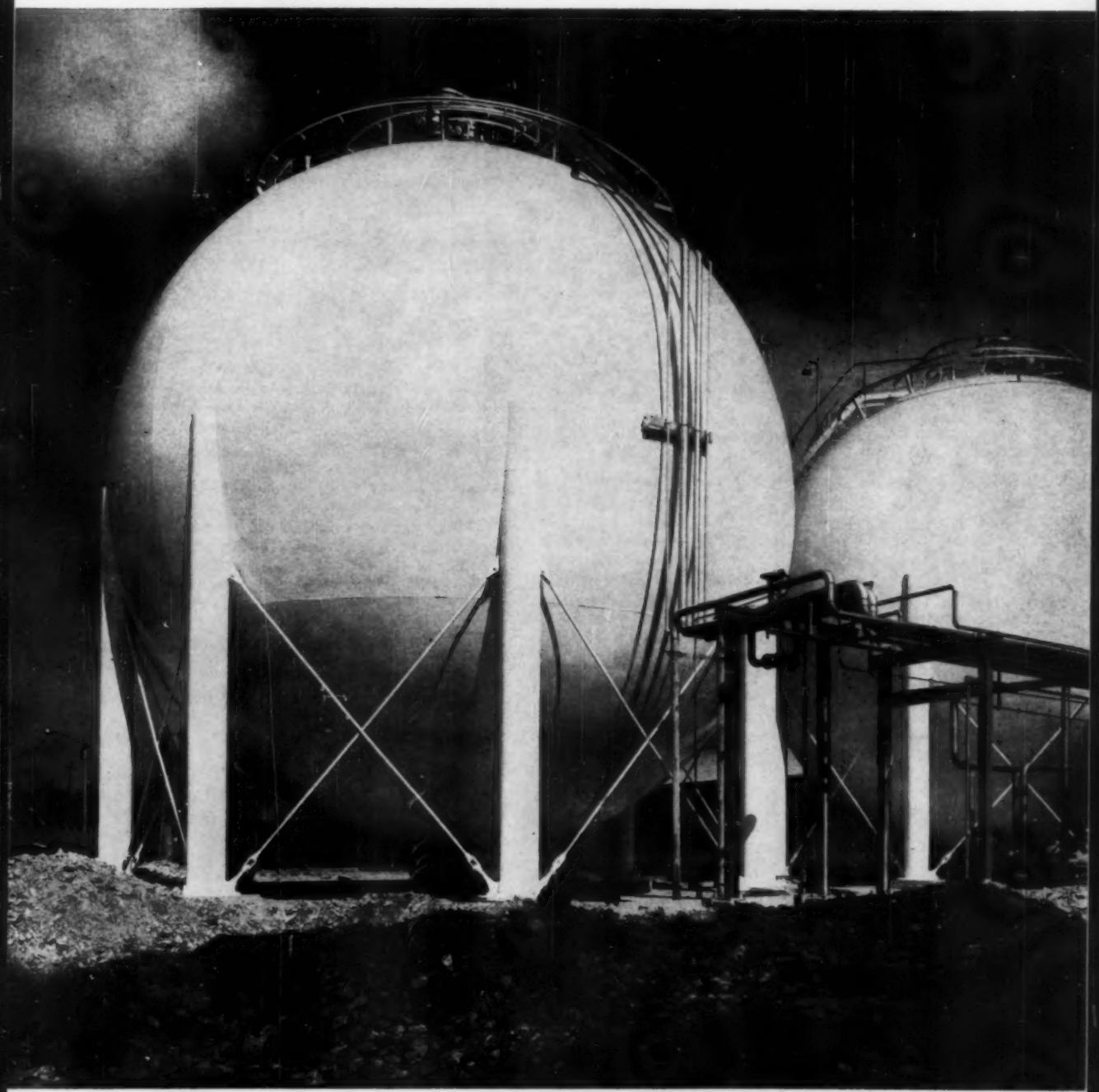
Determine Steam Requirement to be Safe:

This requires trial and error.

Assume various quantities of steam and for each assumption get % fuel in resulting mixture. The assumption where % fuel calculated is equal to that read from the attached curve will give the minimum steam requirement.

The cheapest low pressure waste steam should be used.

Assume 1200 mils per hr steam are required.



Hortonspheres built of USS "T-1" Steel for Compania Cubana Del Nitrogeno, S. A., Matanzas, Cuba.
Designed, fabricated and erected by Chicago Bridge & Iron Company.

This mark tells you a
product is made of modern Steel.

Weight cut 50%

in USS "T-1" Steel pressure vessels

Each of these two Hortonspheres in Matanzas, Cuba, has a capacity of 8,750 barrels of anhydrous ammonia. They are 45.5 feet in diameter and each shell weighs about 311,350 pounds. By designing them with USS "T-1" Constructional Alloy Steel, to an allowable working stress of 32,400 psi, the plate thicknesses were reduced to 1.109 inches and 1.075 inches. This is about 50% less than if A212-Grade B fire box quality steel had been used.

Result: Only 363 tons of USS "T-1" Steel were needed for both tanks, reducing by one-half the amount of steel that would otherwise have been required. Freight, handling, welding and erection costs were less—and the user got a stronger, tougher vessel with an overall saving in cost.

Fabrication steps: Plates of USS "T-1" Steel in widths of 78 inches and 115 inches, and in lengths up to 19 feet 2-1/2 inches, were shaped cold and field stress relieved. Column plates and some shell plates were stress relieved in the shop. Electrodes used in field welding were low hydrogen type of the E110 strength level and all field welds were 100% radiographed. With a minimum yield strength of 100,000 psi, plus toughness, weldability, and high resistance to impact abrasion, USS "T-1" Steel is ideally suited for many applications throughout industry. Write for our latest booklet. United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania. *USS and "T-1" are registered trademarks*

Hortonsphere is a registered trademark of Chicago Bridge & Iron Company

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
National Tube—Pittsburgh
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Supply—Steel Service Centers
United States Steel Export Company
United States Steel

USS

Comp.	Process Mols/Hr	Steam Mols/Hr	Total Mols/Hr	Mol. %
CH_4	164.75		164.75	7.41
O_2	329.50		329.50	
N_2	164.75		164.75	
H_2O Vap.	365.00	1,200.00	1,565.00	
	1,024.00	1,200.00	2,224.00	

$$\frac{O_2}{O_2 + H_2O + N_2} = \left(\frac{329.50}{2224 - 164.75}\right) = 0.160$$

This point falls on the slanted line so 1200 mols per hr is the minimum for safe operation. See Fig. 12 for the locus of points for various assumed steam additions.

$$\text{Steam cost @ } 30¢/1{,}000 \text{ lb} = \frac{(1200)(18)(24)(\$0.30)}{(1{,}000)} = 156 \text{ \$/day}$$

Now another problem appears. Inspection of Fig. 11 shows the fuel concentration to be above the lower limit and thus one may expect it to burn. But it has been found[14] difficult to insure continued burning and good combustion when the heating value is below 100 to 125 Btu per cu ft unburned feed gas.

$$\text{Heating value} = (0.0741 \text{ fraction } CH_4)(920 \text{ Btu/cu ft } CH_4) = 68.1 \text{ Btu/cu ft burner feed gas}$$

Thus methane must be added.

Determine CH_4 and Steam Required for Safety:

Shoot for a final heating value of 115 Btu per cu ft minimum.

This is equivalent to:

$$\%\ CH_4 \text{ required} = \frac{(115)(100)}{(920)} = 12.5\%$$

Since both steam and methane are added, the computation must be a trial and error one.

Assume 1100 mols per hr steam and 150 mols per hr CH_4 must be added.

Comp.	Process Mols/Hr	Additions Mols/Hr	Total Mols/Hr	Mol. %
CH_4	164.75	150.00	314.75	13.85
O_2	329.50		329.50	
N_2	164.75		164.75	
H_2O Vap.	365.00	1,100.00	1,465.00	
	1,024.00		2,274.00	

$$\left(\frac{O_2}{O_2 + N_2 + H_2O}\right) = \left(\frac{329.50}{2{,}274 - 314.75}\right) = 0.1683$$

Plot this point. This shows the combination to be safe.

Now for 150 mols per hr CH_4 added, repeat the above procedure for the steam rates used to get the locus of points for the addition of steam only curve. Then for the same steam rates draw another curve for a constant CH_4 addition of 100 mols per hr and another for 50 mols per hr CH_4.

This will facilitate selection of optimum steam and methane addition rates.

Plot the various values and draw the curves.

An inspection of Fig. 12 will give the minimum safe requirements of steam and fuel gas to be added to the **base of the stack** (to insure good mixing).

The minimum fuel gas flow should be used, since steam is very much cheaper than fuel gas for this operation.

Minimum fuel gas = 80 mols/hr from Fig. 12
Minimum steam = 860 mols/hr from Fig. 12
Use 10 percent safety factor.
Use 90 mols per hr CH_4.
Use 950 mols per hr steam.

Assume fuel gas cost = 18¢/1,000 scf
steam cost = 30¢/1,000 lb

$$\text{Steam cost} = \frac{(950)(18)(24)(\$0.30)}{(1{,}000)} = 123 \text{ \$/day}$$

Fuel gas cost = (90)(379)(24)(\$0.18) = 147 \$/day
Total cost = 123 + 147 = 270 \$/day @ maximum flow

The cost appears high and it is. But maximum flow and possibly all flow occurs during upsets in operation. A ratio controller could ratio both steam and CH_4 to the stack feed and reduce consumption markedly (automatically and simultaneously) by injecting the two only when needed.

Continuous Stack Purge Steam:

There are two reasons for this. The first is to prevent the stack from filling up with air causing localized explosive concentrations should a small leak of fuel occur before the CH_4 and steam valves open. The second reason is to drop the fuel concentration of a very small leak to below its lower limit of inflammability.

The purge steam can be deducted from the requirement calculated above.

A flow of 10 cu ft per minute is recommended[14] for a commercial size burner section.

Assume 10 ft per sec purge velocity is safe. (Design velocity based on burner section ID) say, 30 psig saturated steam will be used.

Temperature = 274 F ≅ 734 R
Pressure = 14.7 psia

$$\rho \text{ Steam} = \frac{(18)(520)}{(379)(734)} = 0.0336 \text{ lb/ft}^3$$

At 10 ft/sec the mols/hr-ft²

$$= \frac{(1.0)(10)(0.0336)(3600)}{(18)} = 67 \text{ mols/hr-ft}^2$$

Size Diameter of Burner Section:

Mols/hr feed gas	= 1024.0	@	167 F
Mols/hr CH_4	= 90.0	@	80 F
Mols/hr steam	= 950.0	@	274 F
TOTAL	= 2064.0 Mols/hr		

Cp CH_4 @ say 200 F = 9.45 Btu/mol
Cp O_2 @ say 200 F = 7.20 Btu/mol
Cp N_2 @ say 200 F = 7.14 Btu/mol
Cp Steam @ say 200 F = 8.10 Btu/mol

A heat and material balance should be run to get the average temperature. For this example the average temperature is 212 F = 672 R.

Average Molecular Weight:

Comp	Mols/Hr	MW	Lb/Hr
Feed	1,024	23.8	24,400
CH_4	90	16.0	1,440
Steam	950	18.0	17,100
	2,064		42,940

$$\text{Average MW} = \frac{42{,}940}{(2{,}064)} = 20.8$$

Assume viscosity = 0.015 cent.

Try 16 in. burner (15.5 in. ID) x-section = 1.310 ft²

Use Crane Technical Paper No. 410.

$$\text{Re} = \frac{(6.31)\,(42{,}940)}{(15.5)(0.015)} = 1{,}166{,}000$$

$$f = 0.0135$$

Burner ≅ 190 ft of pipe

Assume 0.4 psi ΔP; average press. $= 14.7 + \frac{04}{2} = 14.9$ psia

$$\text{Average } \rho = \frac{(20.8)(14.9)(520)}{(379)(14.7)(675)} = 0.0429 \text{ lb/ft}^3$$

$$\Delta P = \frac{(0.000336)(0.0135)(42{,}940)^2(1.90)}{(894{,}660)(0.0429)} = 0.413 \text{ psi}$$

This is less than 0.5 psi maximum allowable.

Use a 16 in. burner.

More than three normal pilots (maybe 6-8) will be required due to low heating value. This is up to the burner manufacturer to recommend.

Blowoff:

$$\left(\frac{\text{Mols CH}_4}{\text{Mols O}_2}\right)\frac{164.75 + 90}{329.5} = 0.742$$

$$\left(\frac{\text{Mols CH}_4}{\text{Mols O}_2}\right) @ \text{ stoichiometric} = 0.50$$

$$\text{Fraction of stoich.} = \frac{0.742}{0.50} = 1.484$$

Rough approximate shows $(g_B)_L = 2{,}000$

$$(U_B)_T = \frac{16.20\,(g_L)^{0.5}}{\left(\frac{\rho}{\mu}\right)^{0.5}}$$

$$\text{Approximate } \left(\frac{\rho}{\mu}\right) = \frac{0.0429}{(0.0177)(0.000672)} = 3{,}600$$

$$\text{Approximate } (U_B)_T = 16.20\left(\frac{2{,}000}{3{,}600}\right)^{0.5} = 12.1 \text{ ft/sec.}$$

This indicates blowoff velocity is much lower than actual stack velocity and pilots are required for stability.

Blowout:

No correlation has been developed to date to predict blowout, because of a lack of data. However, one major manufacturer, for example, states his pilots permit blowout velocities of 400 ft per sec or more. Use the number of pilots recommended by the burner manufacturer.

Height of Stack for Personnel Safety:

Use the formula explained in detail in the text.

The heat release is:

$$CH_4 = 164.75 + 90 = 254.75 \text{ mols/hr.}$$

$$\text{Btu/hr} = (254.75)(379)(920) = 88{,}900{,}000 \text{ Btu/hr.}$$

$$F = 0.20$$

$$K = 1{,}000$$

$$D = \sqrt{\frac{(0.20)(88{,}900{,}000)}{(3.14)(4)(1{,}000)}} = \sqrt{1{,}414}$$

$$D = 37.6 \text{ ft} = \text{Minimum stack height}$$

Use a 50 ft-high stack.

Mr. Ludwig's present address is Rexall Chemical Company, Los Angeles, California.

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A complete bibliography containing 95 references is available from the authors upon request.

Adapted from a paper originally presented by the authors at the Gulf Coast Regional Meeting of the American Institute of Chemical Engineers, Galveston, Texas, October 30, 1959.

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▸ Tennessee Gas Transmission Company, Houston, announces appointment of **Dr. Frank L. Padgitt** to the newly-created post of director of project development. His duties will be connected with expansion and diversification plans of the company in the field of hydrocarbons utilization and petrochemicals.

C. W. Rackley has been named assistant chief of Tennessee Oil Refining Co. He will be succeeded as senior process engineer at the company's Chalmette, Louisiana, crude oil refinery by **A. R. Dudley,** senior process engineer, who is transferring to Chalmette from Houston.

A. E. Bynum, formerly junior engineer at Chalmette, has been promoted to assistant process engineer there.

In the Tennessee Oil Refining Co. division **Dewey Mark** is new manager of petrochemical sales.

▸ **Dr. James F. Wygant,** section head in engineering research at the Whiting laboratories of Standard Oil Co. (Indiana) has been named a fellow of the American Ceramic Society. Since joining Standard in 1950, Wygant has made outstanding advances in applying ceramics, plastics, and insulating materials to uses in petroleum refineries.

▸ **F. P. Coggeshall, Jr.,** is new manager of asphalt for American Oil Co., succeeding **Forrest G. Heath,** who is retiring on annuity after more than 30 years' service with the company. Coggeshall formerly was assistant manager of asphalt.

▸ **Joseph K. Roberts** has been elected a director and appointed as a consultant to Scientific Design Co., Inc., international designers and builders of chemical plants. Roberts retired recently as a director and vice president of Standard Oil Co. (Indiana).

J. K. Roberts

L. R. Hill

▸ **Luther R. Hill** has been named assistant to the vice president of sales for M. W. Kellogg Co. His duties will be concerned primarily with the transition of research and development process results to commercial industrial applications.

Kellogg has appointed **Gordon W. Jones** assistant vice president and director of construction. He formerly was director of technical services.

Thomas E. O'Hare is new staff engineer-economist for Kellogg. He will direct and make economic studies in various fields of Kellogg engineering activity including chemicals, oil refining, pulp and paper, and iron and steel.

▸ **F. H. Lacy, Jr.,** has been appointed manager, natural gas and gasoline division, Honolulu Oil Corp., San Francisco. He formerly was chief engineer of the natural gas and gasoline department in the San Francisco office.

▸ **H. E. Lore,** manager of the engineering and construction department of Dravo Corp., Pittsburgh, has been elected vice president of the National Constructors Association succeeding R. L. Cashen of the H. K. Ferguson Co., Cleveland, who died recently.

▸ **A. Henry Schutte** has been appointed to the senior staff of Arthur D. Little, Inc., international industrial research company. He formerly was vice president of the Lummus Co., designers and contractors for process industries.

A. H. Schutte

C. D. Read

▸ **C. D. Read** is now manager of the manufacturing department of Gulf Eastern Company, subsidiary of Gulf Oil Corporation in Europe, with headquarters in London. Read has been an economist in Gulf's planning and economics department on special assignment which required him to travel internationally to the Far East, Middle East, and Europe.

In Gulf's petrochemicals department **Harry W. Magee** has been appointed special representative—European activities. He will be headquartered in London.

▸ At the Bayway, New Jersey, refinery of Esso Standard division, Humble Oil & Refining Co. **Fred A. Westphal** has been named assistant operations superintendent, **Al Sitarski** has been appointed head of the petroleum products department, and **Jack Grady** has been promoted to head of the mechanical department.

▸ Appointments in the research organization of the Dyestuff and Chemical division, General Aniline & Film Corp.:

Dr. R. L. Mayhew, technical coordinator of acetylene derivatives, surfactants, and chemical specialties, New York.

Dr. J. L. Azorlosa, program manager of exploratory polymer research, Central Research laboratories, Easton, Pennsylvania.

Dr. M. E. Chiddix, program manager of acetylene derivatives and chemical specialties research, Central Research laboratories, Easton.

Dr. S. A. Glickman, assistant program manager of acetylene derivatives research, Central Research laboratories, Easton.

E. Moncrief

J. P. Wiseman

▸ The Fluor Corporation, Ltd., has reassigned two top executives, **Ernest Moncrief** and **James P. Wiseman.**

Moncrief, formerly vice president of the company's Mid-Continent division, Houston, was appointed to the newly created post of vice president and coordinator of foreign operations and affairs. He will operate out of Los Angeles.

Wiseman, who was president of Fluor Products Co., will succeed Moncrief at Houston.

▸ **E. Hearn Simpson** has been appointed Western regional manager for DuPont's Petroleum Chemicals division, succeeding the late Robert F. Harwick. Simpson has been serving as sales manager of the Petroleum Chemicals division, a post which has now been discontinued.

▸ **R. J. "Dick" Boushka** has been advanced to the post of general sales manager of the chemicals division of Vickers Petroleum Co., Inc., Wichita, Kansas.

▸ New president of the American Society for Engineering Education is **Dr. Eric A. Walker,** president of Pennsylvania State University. Other officers are **Dean Melvin R. Lohman,** Oklahoma State University, and **Professor Newman A. Hall,** Yale University, vice presidents, and **Wendel W. Burton,** Minnesota Mining and Manufacturing Co., treasurer.

▸ **L. A. Bullington** and **B. S. Greenwood** have been promoted to senior supervising engineers in Technical Division at Humble Oil & Refining Co.'s Baytown, Texas, refinery. Bullington heads the economic analysis section and Greenwood the butyl and butadiene section.

B. S. Greenwood

L. A. Bullington

▸ American Cyanamid Co. has named **T. Dean Smith** as manager of the petrochemicals department of its Organic Chemicals division, with headquarters in New York. Prior to this, Smith was assistant manager of the company's Fortier plant near New Orleans.

▸ At the Richmond laboratory of California Research Corp., **Dr. D. S. Laity** has been appointed group supervisor, process and plant design section, and **Dr. R. E. Jentoft** has been named senior research chemist in the analytical and physical measurements section.

▸ Four research scientists from Shell Development Co.'s Emeryville, California, research center will spend a year at Shell laboratories in The Netherlands on special assignments. **Dr. G. C. Hood,** Orinda, and **Dr. J. W. Otvos,** Berkeley, will be at the Amsterdam laboratory, while **Dr. G. D. Gailetly,** Sausalito, and **Dr. C. H. Barkelew,** Orinda, will be at The Hague.

Dr. Stanley L. Grotch, San Francisco, has joined the research center staff as an engineer in the chemical engineering department.

▸ **Dr. Randel Q. Little, Jr.,** and **Dr. William W. Sanders** have been appointed group leaders at the Whiting research laboratories of Standard Oil Co. (Ind.).

▸ **Henry C. Speel** has joined Universal Oil Products Co., Des Plaines, Illinois, and is responsible for market research activities of the chemical products department. He formerly was a partner in the chemical consulting firm of Schwarz, Speel and Associates.

H. C. Speel

C. B. Round

▸ **Clarence B. Round,** Ponca City, Oklahoma, has been promoted to manager of manufacturing for Continental Oil Co.'s Rocky Mountain region, with headquarters in Denver. Formerly assistant superintendent of Conoco's Ponca City refinery, he succeeds **W. F. Brown,** who recently transferred to the company's executive offices at Houston as special assistant to the senior vice president.

▸ Recent appointments by Goodrich-Gulf Chemicals, Inc.:

Harvey E. Phelps, manager, mechanical design and construction, headquartered at Cleveland.

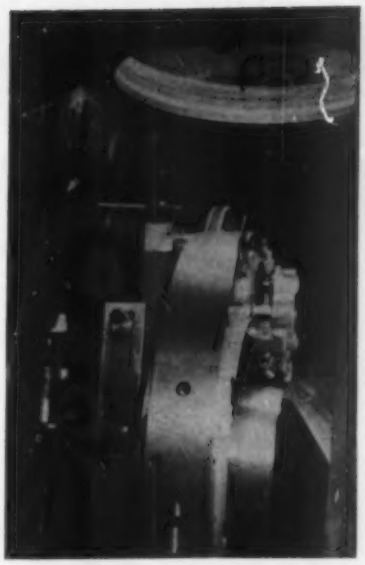
John Sabot, coordinator of manufacturing operations, headquartered at Cleveland.

Bodie C. Pryor, manager polyethylene operations, Port Neches, Texas, plant.

John A. Cover, technical manager, Port Neches, Texas, plant.

▸ **Sidney M. Brunson** has been assigned as project manager for the engineering and construction of the new ethylene dichloride plant of CSRC-Dow Pty. Ltd. at Melbourne, Australia. He has been assistant production superintendent of the vinyl-vinylidene chloride department in the Texas division at Freeport since 1957.

▸ **R. G. Richards,** Painesville, Ohio, has been named to the newly established position of director of development of Diamond Alkali Co. He has served in the Plastics division as project leader, manager of research and development, sales manager, and manager of planning and development.



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Micro-Path Inc., Los Angeles, wholly-owned subsidiary of United Industrial Corp., has formed a new instruments division with acquisition of manufacturing, sales, and distribution rights to all electronic and chemical devices produced by the Robert R. Austin Laboratories, San Gabriel, California.

Brown Fintube Co., Cleveland, manufacturer of heat transfer equipment, has opened sales and engineering offices in Mexico City. **John W. Brown III** will be in charge of the Mexico office.

Bendix has dropped the word "Aviation" from its title and henceforth will operate under the official name "The Bendix Corporation." Approximately 40 percent of Bendix products are electronic.

Pfaudler Permutit SA de CV is now the official name of the Mexican subsidiary of Pfaudler Permutit Inc. Prior to the name change Arteacero Pfaudler and Permutit de Mexico operated using the same offices and plant facilities.

Egloff & Graper, Inc., Los Angeles, has been named California sales representative for environmental chambers and low temperature freezers built by Webber Manufacturing Co., Inc., Indianapolis.

Appointments:

Anthony Amante, export sales manager, and **E. H. Urquhart,** staff sales engineer, Texas Instruments Geosciences and Instrumentation division's Instrumentation Product group, Houston.

T. E. Goodyear, sales manager, St. Louis district, Wolverine Tube division, Calumet & Hecla, Inc.

E. O. Northcutt, Jr., technical service engineer, Catalysts and Chemicals Inc., Louisville, Kentucky.

Harold L. Russell, product sales manager in charge of process instrument sales, Daystrom, Weston Instrument division, Newark, New Jersey.

Nelson Cannon, general manager, Canada, Roger Williams Technical & Economic Services, Inc., with offices in Toronto.

Robert A. Paetz, field sales manager, and **John M. Pogue,** assistant manager for sales development, Tapco group, Thompson Ramo Wooldridge Inc., Cleveland.

Dr. Richard Berger, supervisor, market research, Dyestuff and Chemical division General Aniline & Film Corp., New York.

James H. Bews, manager, San Francisco branch office, Clark Bros. Co.

William P. Simmons, regional sales engineer, San Francisco, and **Robert A. Miles,** district sales representative, Los Angeles, William Powell Co., Cincinnati valve manufacturer.

E. Hearn Simpson, western regional manager, Petroleum Chemicals division, Du Pont.

Robert G. Dow, field salesman, Chicago branch office, Diamond Alkali Co.

Marvin H. Grove, chief executive officer and chairman of the executive committee, Walworth Co., New York. He also is president of Grove Valve and Regulator Co., Oakland, California.

Richard C. Erbes, customer relations manager, Fullerton, California, and **Robert J. Manning,** regional application engineer, Chicago, Scientific and Process Instruments division, Beckman Instruments, Inc.

Robert R. Alpen, Industrial Equipment Ltd., West Vancouver, B.C., agent for INFILCO Inc. in British Columbia.

Lawrence N. Holden, Jr., product manager, Industrial Chemicals division, Pittsburgh Chemical Co., Pittsburgh.

C. W. Beck, vice president, The Pfaudler Co., division of Pfaudler Permutit Inc., Rochester, New York. He also is general manager.

R. J. Schoenenberger, general manager of product sales and chemical products development; **J. A. Neuman,** head of chemical products development; **D. D. Hansen,** manager, McCook, Illinois, plant, and **W. K. Hunter,** head of catalyst sales, Universal Oil Products Co., Des Plaines, Illinois.

Kermit A. Skeie, in charge of commercial inspection; **Denis P. Walsh,** manager of distributor and representative sales; and **Robert G. Strother,** in charge of field engineering, Chicago; and **Richard Turner,** Los Angeles branch manager, and **Henry Bogart,** New York branch manager, Magnaflux Corp.

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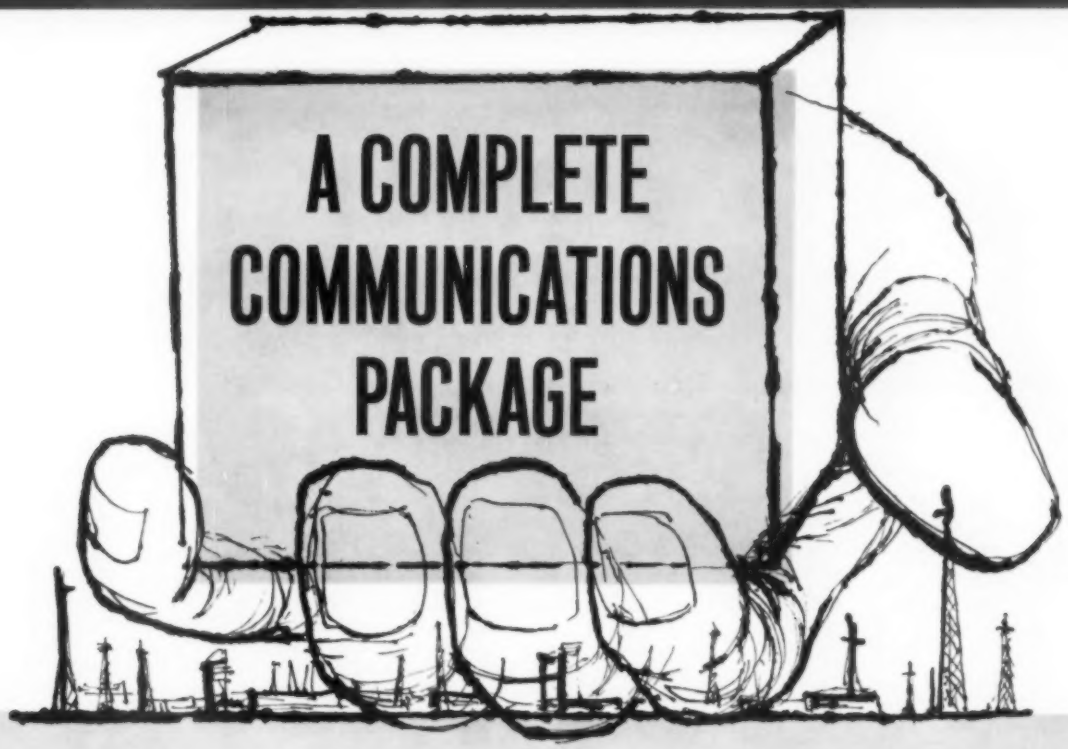

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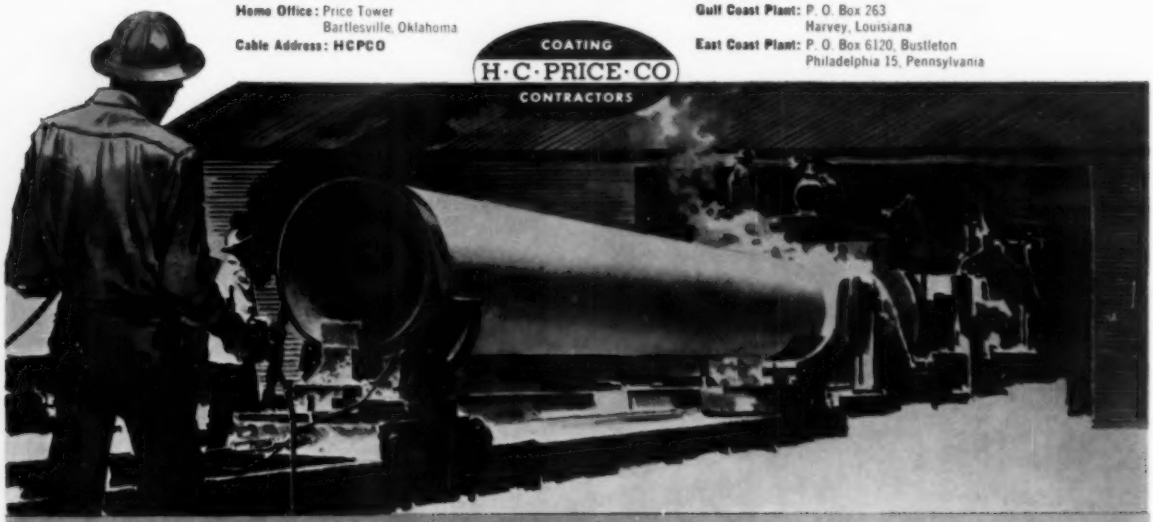

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(a) 1½%; (b) 2½%; (c) 4%.

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(a) 12 years; (b) 17 years; (c) 23 years of service.

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MAJESTIC CONTRACTORS used a Cleveland 190 Backfiller to fill their 52-mile 30-inch job from Wheatland, Indiana to the Wabash River for Midwestern Gas Transmission Company. The 190's ability to keep backfilling up close behind lowering-in operations helped to complete the spread on schedule in spite of heavy rains that hit the job frequently. Two Cleveland 320 Trenchers were used to cut trench to 4-foot width, usually sloped to 7-foot width at the top.

The Cleveland 190 Backfiller—with its new improved water-cooled clutch, raised boom hinges, huskier crawler drive components, and many other refinements—does your backfilling faster, cheaper and better. Check with your distributor now for the latest dope on this one-man-operated, continuous-filling machine with *all* speeds in each direction.

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The CLEVELAND TRENCHER Co.

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TRANSWESTERN
Transwestern's pipeline to carry Texas and Oklahoma gas to the West Coast, largest gas transmission project for 1960, is now scheduled for completion in July. Thus, the more than 1800-mile system will have been laid through some of the roughest terrain under unusually severe weather conditions well ahead of the original target date. Houston Contracting, a prime contractor on the project, is proud to have contributed to this record.
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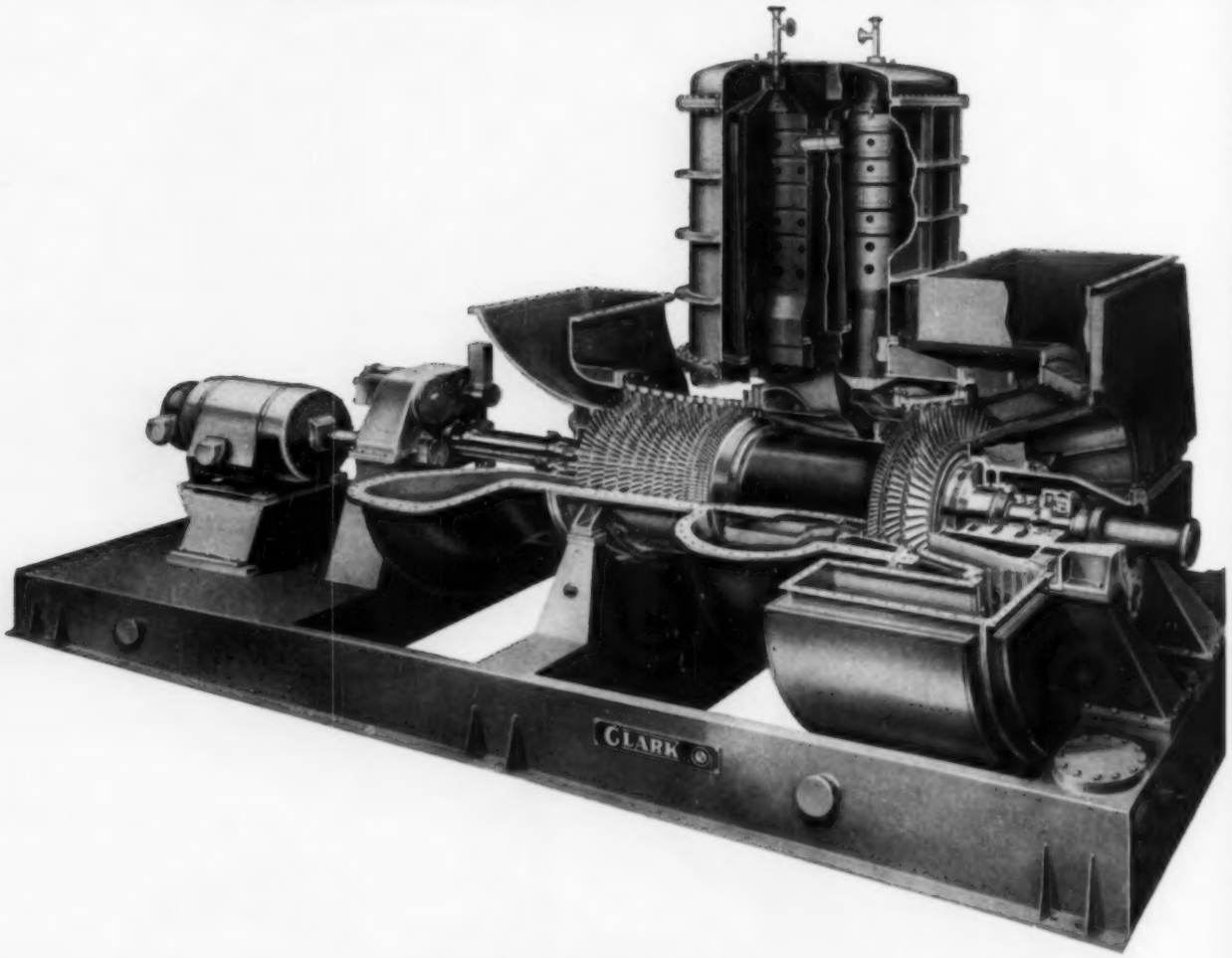

CLARK BROS. CO., OLEAN, N.Y.

CLARK

DRESSER INDUSTRIES INC.
OIL • GAS • CHEMICAL
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ENGINES • GAS TURBINES • COMPRESSORS

the CLARK 300 series of GAS TURBINES measures up fully to your needs

Name the norm . . . capital investment, floor space, installation or operating labor, general reliability, maintenance or all combined. Whatever you use to determine *real* prime mover cost, Clark heavy duty industrial gas turbines provide the most economical answer to your requirements. As an example of how these advantages work for you let us examine the latest addition to the Clark 300 series of turbines, the Model 305-S.

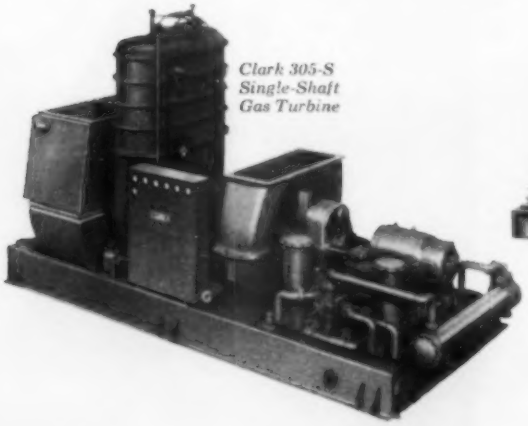
CONSIDER INITIAL INVESTMENT—This single-shaft open cycle machine is simplicity itself. With the axial compressor and three stage turbine mounted on the same shaft, parts . . . *and cost* are cut to a minimum.

FIELD PROVED RELIABILITY—Important components such as compressor and turbine blading are based on proved designs which have operated for thousands of hours in Clark Dual-Shaft Gas Turbines. Turbine inlet temperature is held under 1400° F to ensure extra long life and to provide a substantial margin of operating safety. The turbine is completely air cooled and suitable for operation in arid country. Pressurized air is bled off the axial compressor to cool turbine blade roots and other high temperature components. In addition, cool air envelopes between inner and outer skin surfaces reduce heat loss and minimize heat radiation.

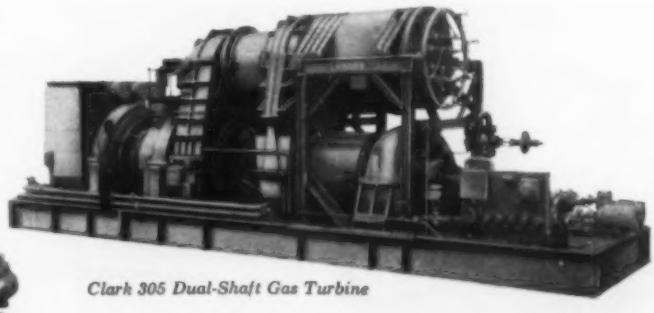
FLOOR SPACE INSTALLATION AND MAINTENANCE—The Clark 305-S is so compact it is mounted on a skid only 26 feet long. The combustion chamber with two parallel burners is placed over the rotor between compressor and turbine. You save on floor space, housing, transportation to the site, foundation and installation expense. Both the single and dual-shaft Clark gas turbine designs have provisions for easy access to blading, bearings and seals for inspection or maintenance.

VERSATILE TOO—Clark Series 300 Gas Turbines in the 8000-10,000 horsepower class provide the inherent flexibility to match the application. The dual-shaft models are excellent drivers for pumps or compressors on liquid or gas transmission lines, for marine propulsion, compressor drivers in repressuring or process plants and other uses requiring broad speed and loading flexibility. For applications that do not require the wide range flexibility of the dual-shaft machine such as base load or peaking turbogenerators the single-shaft units are ideal. Both designs burn either liquid or gaseous fuels.

Your Clark representative will gladly give you all of the cost saving details on Clark Gas Turbines. Consult him or write us direct. CLARK BROS. CO., OLEAN, NEW YORK.



Clark 305-S Single-Shaft Gas Turbine



Clark 305 Dual-Shaft Gas Turbine

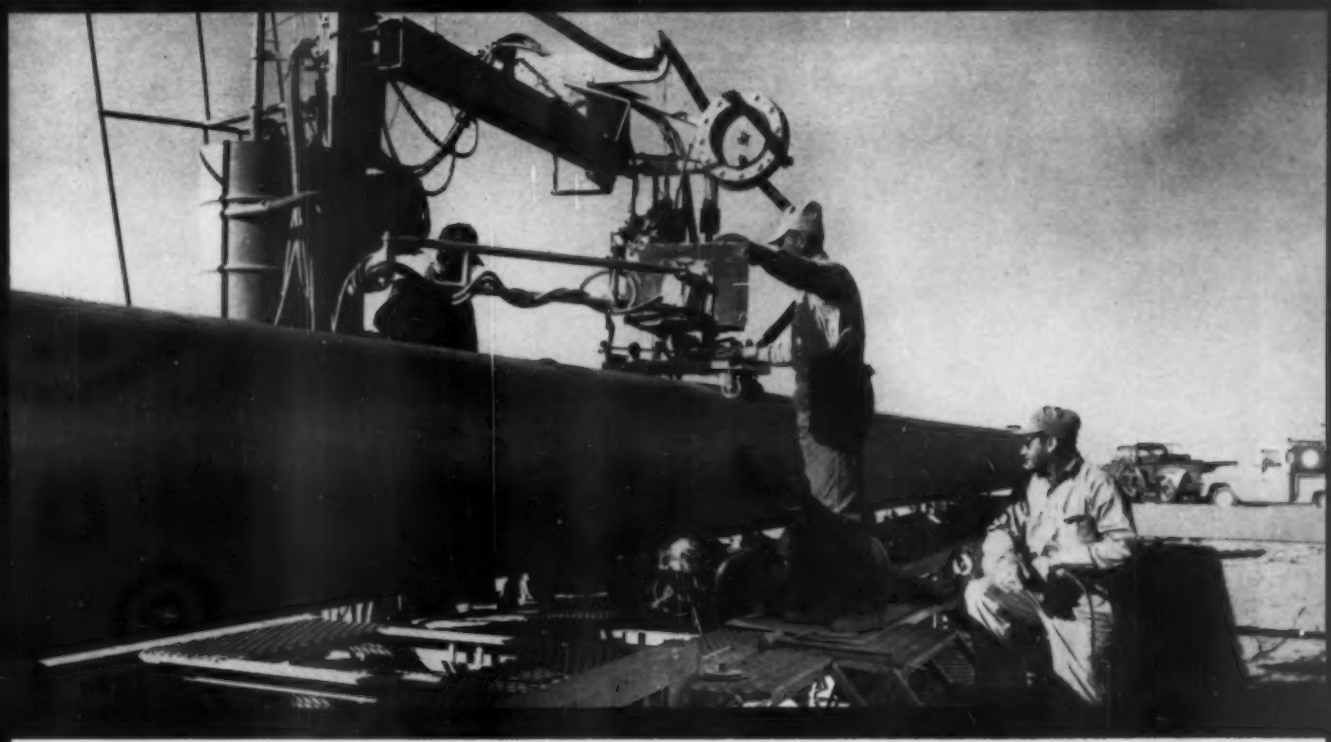
Double-jointing 30-in. steel pipe into 80-ft lengths

speeds Transwestern "big inch" line

Steel *for Strength*
. . . Economy
. . . Versatility

Another product frequently seen on spreads in the Southwest is Bethlehem's electric resistance-weld line pipe, available from 5 9/16 in. through 16 in. OD.

It was plenty cold west of Roswell as the coating and wrapping crews "did their stuff."



Transwestern Pipe Line Company's "big inch" from West Texas to the Arizona-California border is a big job with a big objective —to deliver 300 million cu ft of natural gas per day to Southern California utilities. This calls for the construction of gathering systems and laterals in the Permain Basin of Texas, and in the Panhandle fields. And it requires laying main line of 30 in. OD pipe from Roswell, New Mexico, clear to the California-Arizona border.

Double-jointing in the field

There's plenty of Bethlehem Line Pipe on the job, including the entire distance between Compressor Stations Eight and Nine west of Roswell. On this spread Houston Contracting Company used a new technique—double-jointing the pipe in a yard with special pipe handling and automatic welding equipment. The 80-ft joints mean more footage per truckload, cutting both delivery time and costs. It also resulted in excellent, low-cost welds, with a corresponding reduction in the number of slower, costlier field welds.

Gulf Interstate Company is handling a major portion of the engineering and design of the Transwestern project.

You'll find Bethlehem Line Pipe in all diameters on spreads throughout the land. It's good pipe, made to the highest standards on mills that rank with the finest. We'd be happy to give you more information. Just contact the Bethlehem sales office nearest you.

NOW AVAILABLE IN ALL SIZES MEETING API SPECIFICATIONS

	SIZES (in., OD, incl.)	WALL THICKNESS (in.)	LENGTHS	SPECIFICATIONS
HYDRAULICALLY EXPANDED ELECTRIC FUSION-WELD (submerged arc)	18 to 42	¼ to ¾ incl.	40 ft	API 5LX, Grades X42, X46 & X52 Also X-56
ELECTRIC RESISTANCE-WELD	5⅝ to 16	API	to 60 ft	API 5L, Grades A & B API 5LX, Grades X42 & X46
CONTINUOUS BUTTWELD	⅛ to 4½	API	SRL 24 to 26 ft DRL to 50 ft	API 5L

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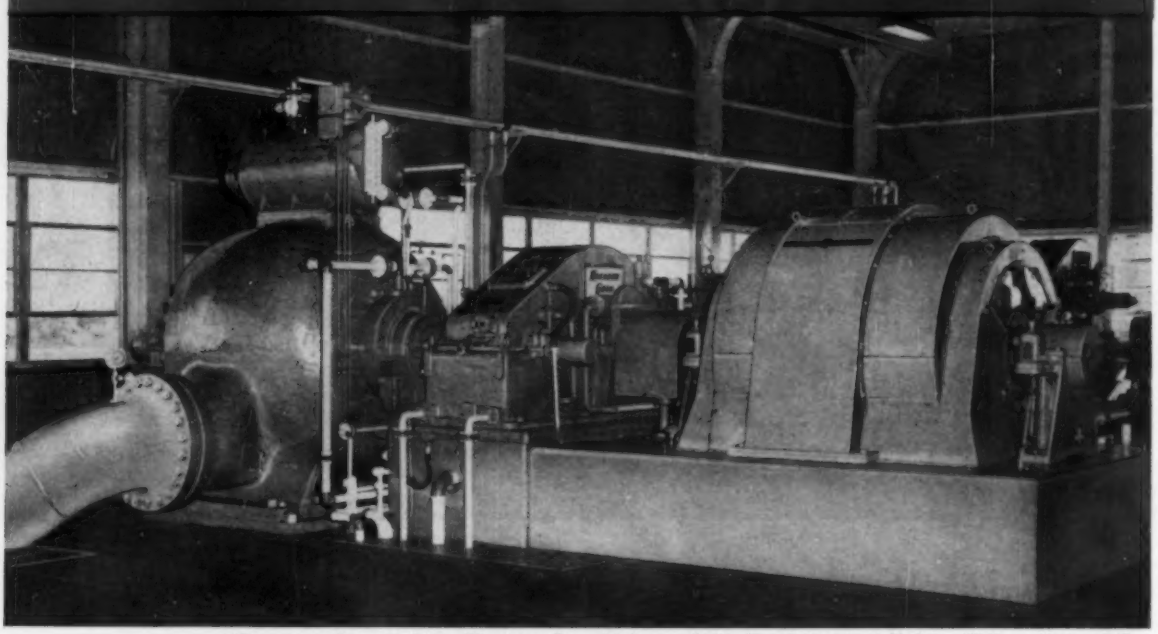
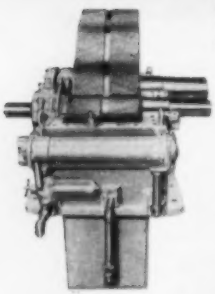
BETHLEHEM STEEL

WESTERN GEAR

pipeline drives on stream at EL PASO NATURAL'S LEUPP STATION



Foreground: one of two Western Gear high speed pipeline drives installed for El Paso Natural Gas Company in its Leupp Station, Leupp, Arizona. Both drives are catalog model 300 HS 150 units, rated at 5750 h.p., with input of 1200 r.p.m. and output, 8494 r.p.m.



on the long run . . .

QUALITY COSTS YOU LESS!

Where there is obviously no compromise with quality, you'll find Western Gear. El Paso Natural Gas Company's Leupp Station, using the Ingersoll-Rand compressor powered by a General Electric Motor, is an example of reliance on Western Gear where performance and dependability are vital.

Pipeline companies throughout the world rely on Western Gear hi-speed gear units. Western Gear single stage pipeline drives are in use by Texas Eastern, Transmountain, Warren Petroleum, Union Oil, Trans-Arabian, Petroleos Mexicanos, Spanish Pipeline, Richfield Oil, Great Lakes and Mid Valley. Transwestern and Columbia-Gulf, using engine driven centrifugals are equipped with two stage high speed units, an application pioneered by Western Gear.

But pipeline experience is not the whole story. At Western Gear, many products are built requiring extremely close tolerances and rigid quality controls, including Magnafluxing and X-Ray and ultrasonic inspection. These range from 45,000 h.p. marine drives to highly loaded, lightweight gears, and super-precision drives for speeds to 100,000 r.p.m. and gear pitch line velocities approaching the speed of sound.

In such an environment, design and production of high speed pipeline drives falls easily within the scope of Western Gear's everyday experience.

For full information on Western Gear pipeline drives, write, wire or phone: WESTERN GEAR CORPORATION, Industrial Products Division, P.O. Box 126, Belmont, California, Phone LYtel 3-7611.

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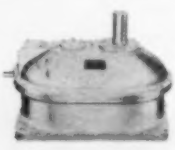

VERTICAL SHAFT REDUCER

HIGH SPEED UNIT

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Once you install 2-way radio, you'll come to *rely* on it. You'll build your business procedures around it—because that's the way this new business tool is most profitable. For maximum profit, you'll insist upon premium reliability . . . day-in, day-out dependable performance. That's why you'll be glad you bought Motorola 2-way radio! And for two good reasons. ■ First, because records prove Motorola 2-way radio outperforms all others—requires less repair—experiences far fewer outages. Second, Motorola will supply regular, programmed maintenance and assume complete responsibility for the continuing peak operation of your system. ■ For routine or emergency maintenance your Motorola Service Center is "Johnny on the Spot." Motorola Service is *nearby;* over 800 Service Centers. And Motorola Service is *fast*—a radio-dispatched "repair shop on wheels" with factory-trained personnel using factory-perfected methods, tools and test equipment is at your command. ■ Motorola reliability—from sale through service—is one of the big reasons why the people who buy the *most* 2-way radio—fire, police, utilities, construction, transportation services—buy Motorola 2-way radio *more often than all other makes combined!* ■ When *you* buy—give yourself premium Motorola performance.

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Motorola Communications & Electronics, Inc., 4501 Augusta Blvd., Chicago 51, Ill.
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Service finds polyester resin reinforced with glass fiber strong enough to seal sizeable leaks and impervious to corrosion

CORRODED TANK BOTTOMS REPAIRED WITH PLASTIC

DICK GAVITT
Service Pipe Line Company

1. Base plates for supporting legs of floating roof are covered first. Here, workman smooths glass fiber matte over heavy layer of polyester resin, which was sprayed on tank bottom.

USE OF A PLASTIC MATERIAL to repair a badly corroded tank bottom has been tested successfully in field service by Service Pipe Line Company at its Drumright, Oklahoma, pump station. Work is already under way on similar projects elsewhere on the company's crude oil pipeline system.

The material, identical with that currently being used for building small boat hulls and light automobile bodies, is polyester resin, reinforced with glass fiber matte. It is exceptionally strong, and its cost under normal conditions is less than that of other methods of permanent tank bottom repair.

The use of resin-impregnated glass fiber in crude oil service was considered, experimentally, as long ago as 1954. At that time, however, high costs and inferior methods of application prevented pipeline engineers from arriving at any practical solution.

The method used by Service was developed under the direction of Tank Superintendent R. Merle Carter. He drew on his wide experience with plastic boats and boat building in his search for a material that would be relatively inexpensive and easy to apply, but at the same time would be chemically resistant and as strong as a new tank bottom.

Internal-External Corrosion

The first opportunity to put reinforced glass fiber to an operational test came in late 1959, when a 107,000-bbl, floating-roof tank at Drumright developed a bottom leak and was taken out of service. Carter and others examined the tank after removal of basic sediment. The bottom not only showed extensive internal corrosion, but was weakened by external corrosion as well.

The use of a thin film coating of one of the coal tar epoxies would have been considered had only internal corrosion been involved. Such thin films, however, are not sufficiently strong to bridge the holes that might be expected to develop as the result of corrosion from beneath the tank.

In this case, it was determined that a new bottom was needed — and that reinforced glass fiber could be applied at less cost than either a steel or a concrete bottom, with equal or better long range results.

The material to be used was basically a glass fiber matte, 1/16 in. thick, thoroughly impregnated with liquid polyester resin. This resin is of the type that is cured by catalytic action rather than by the evaporation of solvent. The final result, after curing, is a hard, cohesive substance of great membrane strength.

Tested for Six Years

Tests of the material had been carried out, from time to time, over a period of nearly six years. Laboratory experiments in 1954 and later had proved that reinforced glass fiber was sufficiently resistant to chemical action to make it practical for crude oil service.

Hydrostatic tests to determine its strength were made in Service's Tulsa shops, using a prepared sample. A 1/16-in. layer of glass fiber, impregnated and cured, was used as a blind gasket between two 6-in. pipe flanges and was subjected to pressure. The effect was to simulate a hole 6-in. across in a tank bottom.

2. Hand application of additional resin is given to insure thorough impregnation of matte.

3. Spray is used to apply resin on tank bottom, which has been prepared by use of one coat of wash primer to improve adhesion.

Pressure on the glass fiber was increased to 45 psi before the sample ruptured; approximately three times the pressures encountered in actual service. Under compression, the material was found to be stronger than steel plate of similar thickness. Its tensile strength was determined to be 8000 psi — a figure that could be increased above 30,000 psi by the use of a combination of matte and woven cloth, if such extra strength were necessary. However, uses currently planned for the material do not require this more complicated, more expensive material.

Application Method

Service's method of application, as used at Drumright, is to lay the new glass fiber floor directly over the old steel bottom. After the BS & W was removed and the tank cleaned, the bottom was sandblasted.

Existing holes were patched—in this case with steel patches, although the patching could have been done with extra thicknesses of the impregnated glass fiber itself. One coat of wash primer was applied as a rust inhibitor to protect the steel while the new bot-

4. Glass fiber matte, 1/16 in. thick and 50 in. wide, is laid over freshly-applied resin coating. Curing, which requires only a few hours, results in tough, durable chemically-resistant bottom covering.

tom was being laid, and to improve adhesion.

The actual laying process began with the spraying of a heavy film of resin on to the steel bottom, working in strips. The glass fiber matte, weighing 1½ oz per sq ft, was then laid down from 300-ft rolls, 50 in. wide, on top of the resin film. It was smoothed down, and compressed with rollers to promote saturation from the underlying resin and to eliminate air pockets.

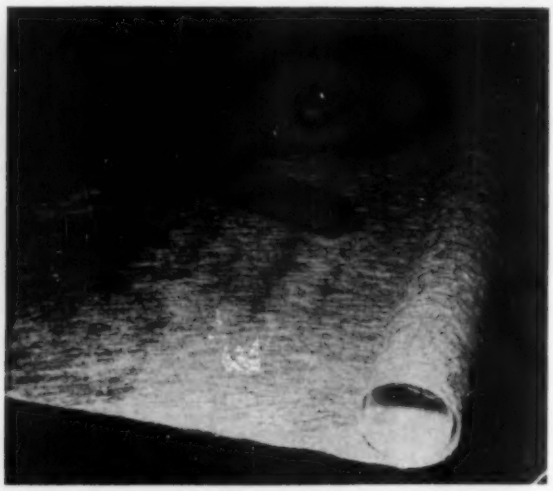
More resin was sprayed or poured on top of the matte, where necessary to provide complete saturation. Rollers were then used to finish spreading the resin and work out any air bubbles.

It is important that every fiber in the matte be thoroughly impregnated with the resin and that all entrapped air be worked out. Best results were obtained when sufficient resin was laid down in the first coat to saturate the matte with a minimum of top-side application.

The material cures in a few hours to a hard, tough, chemically-resistant covering that is strong enough to seal sizeable leaks in the tank bottom, and is impervious to corrosion.

In some instances, as in the case of riveted tanks or along the seams of welded tanks, it is desirable to give certain areas added strength. This may be done simply by stripping the joints with matte and resin before proceeding with the continuous layer. In order that the polyester resin can be more easily and thoroughly worked into the matte, ambient temperatures should be 50 F or higher.

The hand method of application was used by Service in order to maintain positive control of thickness and quality. Machine methods of simultaneously spraying chopped fibers and resin are available, and may be used on later projects where thicker coverings are needed and additional costs are justified.



5. Important step in applying glass fiber matte is smoothing and compressing with rollers. This eliminates air pockets and promotes saturation from the underlying resin.

Saved: $6000

Service can point to a clear saving of some $6000 on the Drumright job alone, as compared with the next least expensive method: pouring a concrete bottom. Half that amount was saved in the cost of the material, the other half because with the thin, glass fiber bottom it was not necessary to change or relocate any of the tank fittings. The cost of materials for the reinforced glass fiber is figured at approximately 70 cents per sq ft.

While the Drumright project was Service's first use of glass fiber and polyester resin to form tank bottoms, it will not be the last. At least three more jobs are now being planned, and still others are under consideration. The new material is not regarded as a panacea for all tank-corrosion ailments. It is, however, a valuable asset to the pipeline industry in helping to lick one of its toughest economic problems. ★ ★

6. Hand method of application insures positive control of thickness and quality. Significant cost savings were realized through use of plastic material on tank bottom.

Bellhole line-up and welding crew.

Why Pacific Lighting Chose

BELLHOLE CONSTRUCTION

With conditions favorable on new line that meets Transwestern system, influencing factors were: (1) Lower cost, (2) better coating quality, (3) less pipe stress, (4) less manpower, and (5) fewer shutdowns due to high winds

MAURICE E. FULLER, *Chief Engineer, Pacific Lighting Gas Supply Company*

PACIFIC LIGHTING Gas Supply Company, in December 1959, took bids for construction of 116 miles of 34-in. pipeline in the Mojave Desert between the Colorado River and Newberry, California. The new line is a link in the facilities to deliver gas from Transwestern Pipeline Company to Southern California.

Because the route is through terrain for the most part free of steep slopes, which would make it difficult to fit pipe to the ditch, specifications gave the contractors the option of using either bellhole or over-the-ditch construction.

The joint venture bid of Pacific Pipeline Construction Company and Engineers Limited Pipeline Company was the lowest, and was based on bellhole construction. Three bidders submitted proposals for both bellhole and over-the-ditch construction and seven for bellhole only. The type construction proposed by the bidders is listed below in the order of increasing bid price:

Construction Method	Percent of Low Bid
1. Bellhole.	100.0
2. Over-the-ditch.	102.2
3. Bellhole.	102.3
4. Bellhole.	102.4
5. Bellhole.	105.6
6. Bellhole.	106.2
7. Over-the-ditch.	118.6
8. Bellhole.	122.8
9. Over-the-ditch.	125.6
10. Bellhole.	126.9
11. Bellhole.	127.6
12. Bellhole.	134.4
13. Bellhole.	134.9

Since Pacific Lighting Gas Supply Company decided on the bellhole method of construction for its desert pipeline that meets the Transwestern system at Needles, California, the question has been asked many times why this method was selected in preference to over-the-ditch construction. The question was answered by the company's chief engineer, Maurice E. Fuller, at the Pacific Coast Gas Association Transmission Conference in Salt Lake City, Utah, May 26-27. His paper is published here. — Editor's Note.

The average cost for bellhole construction was 0.70 percent more than that bid for an over-the-ditch job. Pacific Lighting Gas Supply Company had estimated that a bellhole construction contract would cost about 4 percent more than over-the-ditch.

Unusual Operating Conditions

Special requirements not normally a part of Pacific Lighting specifications apply to this 34-in. pipeline installation because of the unusual operating conditions anticipated.

The pipeline will operate at elevated temperatures, subject to the possibility of a range between 50 F and 135 F. This differential, together with the internal gas pressure, could produce a maximum of 990,000 lb longitudinal loading on the pipe.

Although a 225 F softening point coal tar enamel was used, it was assumed that none of the axial load would be transmitted through the coating to the soil. This assumption was made because the maximum differential temperature is expected to occur on an annual cycle and the enamel would be subject to "cold flow" during six months on each half of the cycle. Thus, the pipeline would be subject to an alternating axial load in straight sections and a reversing bending moment in curved sections.

These conditions indicated the need for special steps to keep secondary stresses at a minimum.

Special Requirements

Pipe used is 34-in. OD, 0.469-in. wall fabricated in accordance with API 5LX52 Specifications. To achieve the sound welds necessary under the expected loading, specifications required retention of the line-up clamp in place during 100 percent of the time the stringer bead was applied, and that there be no movement of the pipe until the first hot bead had been applied.

Anchors were required to limit the bending moment. Or, as an alternate to anchors, the contractor was given the option of keeping the radius of side bends and over bends sufficiently long so the pipeline would behave as a column. With increased cover on over bends, the contractor was permitted to shorten the radius at those bends. No special restriction was placed on sag bends other than to assure smooth bends in compliance with ASA B31.1 Section 8.

The line has been constructed through the most rugged terrain on the route and thus far grading and trenching have been done so that no anchors have been necessary.

Unique Welding Procedure

The contractor devised a unique procedure to line-up and weld the pipe in compliance with specifications. His equipment consisted of four sideboom tractors and a tractor on which were mounted four welding generators. While the root bead was welded, the following functions were performed by the tractors:

The lead sideboom picked up and held a single 80-ft joint at the midpoint, in position ready for line-up upon completion of the first hot pass weld on the previous joint.

The second tractor was ready to support the leading end of the joint being welded, but no lift was made until the hot pass was completed on the previous joint.

The third tractor was supporting, at the midpoint, the joint of pipe being welded.

The fourth tractor was supporting the end of the joint being welded at a point immediately behind the weld.

As soon as the root bead was applied, the internal line-up clamp was released. The third and fourth tractors moved ahead while the welders remained in position and applied the first hot pass.

These tractors then became the first and second tractors, respectively, doing the work described above.

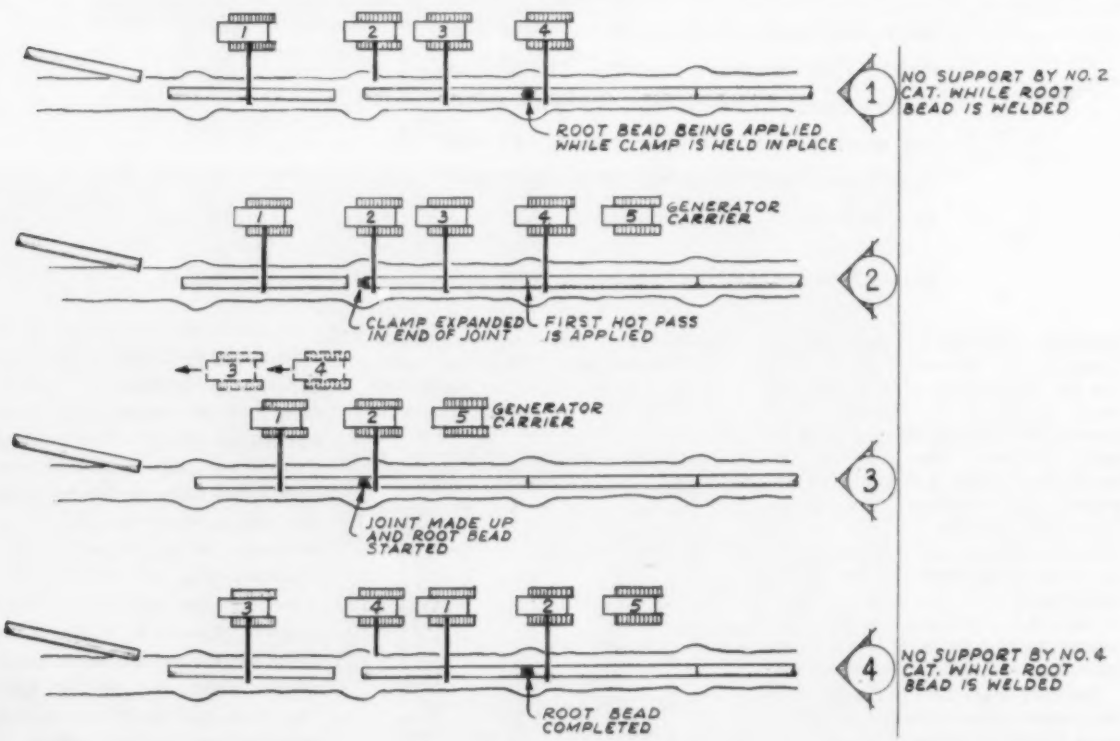

1
2
3
4
ROOT BEAD BEING APPLIED WHILE CLAMP IS HELD IN PLACE
NO SUPPORT BY NO. 2 CAT. WHILE ROOT BEAD IS WELDED
5
GENERATOR CARRIER
CLAMP EXPANDED IN END OF JOINT
FIRST HOT PASS IS APPLIED
JOINT MADE UP AND ROOT BEAD STARTED
ROOT BEAD COMPLETED
NO SUPPORT BY NO. 4 CAT. WHILE ROOT BEAD IS WELDED

FIG. 1. Bellhole line-up procedure.

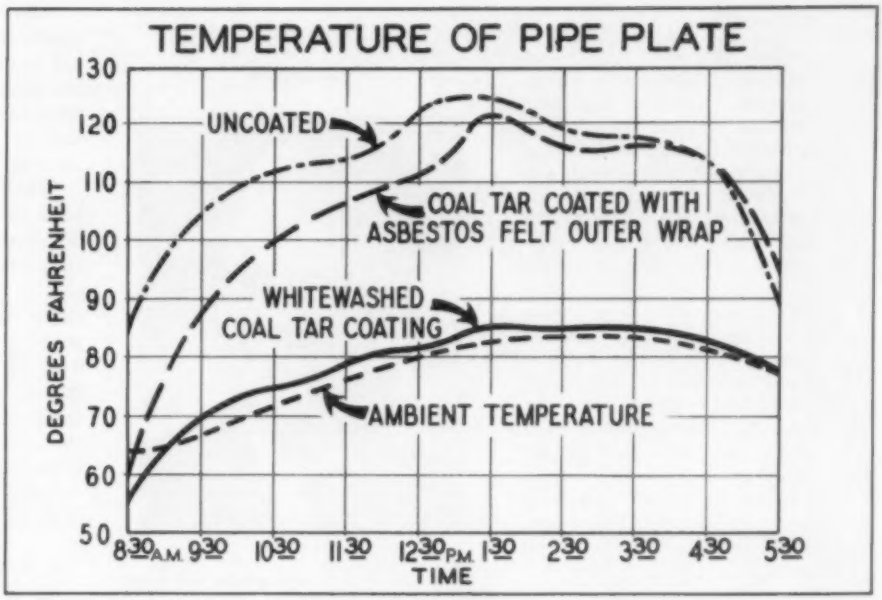


FIG. 2. Effect of whitewashing the pipe, which was done to keep it relatively close to expected operating temperature.

As soon as the first hot pass was completed, the welders moved forward and applied the stringer bead to the joint between tractors No. 1 and No. 2. While the stringer bead was being applied, tractors No. 3 and No. 4, respectively, moved to the lead ready for welding to start on the next joint, completing the cycle.

In order to make the greatest possible progress, the contractor used four welders on line-up at all times. Immediately upon completion of the stringer bead, the same welders applied the first hot pass. A fifth welder was assigned to the line-up and hot pass crew as a relief man to aid further in keeping the production at the maximum rate.

Preliminary work was begun in January; welding on February 11, with completion of construction June 25. Progress was at an average rate of 5750 ft per working day. The maximum lined up, welded, and lowered in 9 hours' work time was 8640 ft.

Some Limitations . . .

There are obvious limitations to the use of bellhole pipeline construction. It is not well suited for an area with high ground water or frequent rainfall. The cost of bellholes in very rocky country would be prohibitive. Also, the speed of construction generally will be less with bellhole than with over-the-ditch construction.

. . . But Many Advantages

Pacific Lighting Gas Supply Company sees a number of advantages in a bellhole job. In the first place, the pipeline is lowered in place in conjunction with welding. Therefore, the pipeline can be constructed in continuous strings without coating damage by skids as the ambient temperature fluctuates. Because the 34-in. pipeline will operate at higher than normal temperatures, the contractor is permitted to weld the pipeline in a continuous string when the ambient temperature is not less than 50 F nor more than 90 F. Pipe coating was whitewashed in order to keep the pipe relatively close to the expected operating temperatures, in spite of the desert heat during construction. Fig. 2 shows the effect of whitewashing the pipe.

As there was a differential in the plate temperature on the sunny and shady sides of the pipe, the temperature was measured on the inside of the side exposed to the sun, as well as 180 deg from that side. When the average of the two temperatures exceeded 90 F the contractor was required to leave breaks in the line to be tied in at a time when the temperature was between 50 and 90 F.

Although the characteristic of a coated pipe when the coating is black will be to have excessive temperature increase on a sunny day, this tendency is greater with bare pipe. However, the insulation afforded by a coating tends to keep coated pipe warm later in the afternoon than bare pipe.

Pipe Diameter a Factor

Diameter of the pipeline also is a factor in selecting the method to use in constructing a pipeline. Probably a 24-in. pipeline would cost more constructed by bellhole than over-the-ditch. Experience indicates that where the method is applicable, however, 30 or 34-in. diam pipelines can be constructed at lower cost by the bellhole method than over-the-ditch. As diameters increase in the future, it is the opinion of the writer that this trend will continue.

Because bellhole construction requires excavation and a field joint at intervals equal to the length of the pipe joints, it is generally the practice to double-joint pipe. Hauling problems may be encountered due to load length limitations by highway authorities and curved roads in rugged country.

Pacific Pipeline Construction Company had the contract to double-joint and coat the pipe with a high melt point coal-tar enamel, glass inner wrap, and an asbestos felt outer wrap.

Its welding equipment applied one submerged arc pass each on the inside and then the outside of the pipe after it was first lined up and tacked manually.

Enamel Delivered in Bulk

The coating process incorporated a "first" for a coal-tar job. Molten enamel was delivered in bulk from the Koppers, Inc., Fontana plant in specially equipped truck tanker and trailers.

Each combination rig was capable of delivering 52 tons per trip. Initially, the trucks and trailers were insulated only, but it was found that after a few loads the filler dropped to the bottom and the tank surfaces became coated with solid enamel. It was necessary to install agitators to keep the filler from settling and to circulate the enamel to

prevent too rapid cooling at the tank surface.

The longest haul was 240 miles between Fontana, California, and Henderson, Nevada. During the 7½ to 8½ hours required in transit, the enamel cooled from 550 F to temperatures that varied between 410 and 450 F. This probably represents the practical maximum hauling time without application of heat enroute.

More field patching of coating is required in bellhole construction because of coating damage when pipe is bent, and the need for field joints. These disadvantages can be minimized by bending pipe at the proper temperature when the coating is pliable. Also, certain field jointing materials now available reduce the labor and enamel formerly needed.

The advantages gained in bellhole construction of 30-in. and larger pipelines are believed to outweigh the disadvantages.

Here Are the Reasons

Reasons for Pacific Lighting Gas Supply Company's preference are:

1. Cost.

Because fewer tractors are required than on the ususal over-the-ditch spread, and lighter tractors can be used, the cost can be lower. Usually three or four sideboom tractors will take care of the line-up crew. And, instead of having tractors following behind lowering in, this operation is done with the line-up.

Backhoes or clams, depending upon the soil, will be used to excavate bellholes. At least two pieces of such equipment will be required. The cost of backhoes is less than that of the more costly sideboom tractors, which will be needed in greater number for over-the-ditch construction.

2. Quality.

The greatest single advantage Pacific Lighting sees in the bellhole method is that the protective coating is of a higher quality than can be achieved with a traveling coating machine. With a yard set-up, the pipe is grit blasted and, if necessary for a good dry surface, it can be heated before blasting. With the pipe cleaned down to a gray metal surface, the primer will produce the best bond possible.

In cold weather pipe can be preheated prior to application of the enamel to assure a uniform coating thickness. It is also possible to pour a strip of enamel along the longitudinal seam and around the double joint circumferential seam so no strip of reduced coating thickness exists.

Because of better control with stationary equipment, it is possible to keep the thickness of the coating within 10 mils of the specified average required over the entire pipe surface regardless of weather conditions.

Pipe damage is easy to control. Wherever the coating is gouged, easy-to-see evidence is provided the inspectors. It tends to make a contractor more aware of the need for careful pipe handling.

Double-joint welding, which is done at a railhead location, normally is better quality than that attained on the pipeline right-of-way. On a job of sufficient size to justify a welding yard, automatic submerged arc welding equipment generally is used. Because the pipe is on racks, it is easy to get whatever percentage of the weld's X-ray is desired.

Another feature that results in a quality installation is the close fit that can be achieved between the pipe and the bottom of the ditch. In this way secondary stresses, which are impossible to analyze, are at least kept to the minimum possible level.

Bellhole installation by our company of an 80-mile, 34-in. line in 1958, one of several, was made in winter rains and snow. About half of the route was over a mountain range having steep slopes and presenting a construction problem of considerable difficulty. Results were entirely satisfactory. Welding and protective coating quality were excellent; the pipeline fit the ditch. The entire 80 miles of pipeline is now under cathodic protection with a total current drainage of 2.7 amp, indicating a high order of protective coating quality.

3. Less manpower.

On a 34-in. bellhole job, the total number of men for a single spread usually will vary between 200 and 225 on the actual pipe laying operation. In addition, there will be approximately 50 men engaged in double-jointing and coating the pipe. The usual number on an over-the-ditch job is about 300 men, or 25 to 50 more than required on the bellhole installation.

4. Continuity of work.

Work is less subject to shutdown because of wind. As the work is performed in the trench, welding is afforded protection against high heat transfer rates. This becomes particularly important in the southwestern part of the country where frequent high winds interfere with the welding progress on a pipeline job.

Based on the results attained in the 1958 job and the anticipated good success in the current work, Pacific Lighting Gas Supply Company is well pleased with bellhole construction. We feel a top quality pipeline can be built in this manner. It provides a means, in our opinion, of meeting realistically the welding problems described in the American Gas Association Research Project NG-10 "The Effects of Welding Procedures on Base-Metal Cracking Adjacent to Girth Welds and Welded Connections in Natural Gas Pipe Lines," and at no premium in cost.

Where conditions are favorable for its use, it is our conclusion that any pipeline project should have consideration given to the possibility of construction by the bellhole method.

* * *

THE AUTHOR

M. E. FULLER was graduated from the University of California at Berkeley with a BS in civil engineering in 1942. Immediately after graduation and until January 1944, he worked with the Pacific Electric Company as a junior engineer. From January 1944, to July 1946, he served in the Naval Reserve with the rank of Lieutenant, JG, working in Aviation Ordnance. In July 1946, he started working with Pacific Lighting Gas Supply Company as division engineer, and in 1950 was promoted to supervising engineer. On June 1, 1957, he was appointed chief engineer.

Engines at Colorado Interstate's Springfield compressor station are now governed by an automatic control system. The engine control panel shown here is one of four.

Automatic Compressor Station
Is Remotely Supervised

CIG TAKES STEP TOWARD AUTOMATION

Portion of Colorado Interstate's Communications Control Center. Console and monitor for the automatic control system are at the rear left.

THE FIRST remotely supervised automatic compressor station on its system has been placed in service by Colorado Interstate Gas Company. The control system, headquartered in Interstate's Communications Control Center at Colorado Springs, supervises the Springfield compressor station, in southeastern Colorado, approximately 160 miles distant.

All station regulating functions, including engine selection, are under direction of controls within the station, differing from remote control operation in which these functions are handled by the dispatchers.

Participating in a button-pushing ceremony that inaugurated use of the control system were N. B. LauBach, vice president in charge of operations for Interstate, and G. A. Peck, president of the Southwestern Industrial Electronics Company, Houston, Texas. SIE was the prime contractor for the automation system.

Interstate's Springfield station was built in 1953 and is equipped with four Cooper-Bessemer two-cycle engine

compressor units with a total of 5400 hp. The Springfield station pumps gas received from Texas, Oklahoma, and Kansas into the Rocky Mountain market area.

As is known, gas flow through a transmission company's lines is regulated by the discharge pressure maintained at the various compressor stations. To increase flow when market demands rise, discharge pressure at the compressor stations must be raised. To decrease the gas flow, discharge pressures are reduced.

Under normal procedure, to effect a change in station pressure the gas dispatcher, at the control center relays instructions to the crews that man the compressor stations on a 24-hr basis. These crews then manually make the necessary adjustments.

Through use of the automatic control system, Interstate's gas dispatcher can now telemeter over microwave communication channels the discharge pressure figure, or set point control as it is known, to the compressor station set point controller. This then resets the set point of the discharge pressure controller at the desired level.

The discharge pressure controller compares the actual discharge pressure with the set point and changes the speed of the engines in service to obtain the correct pressure. If the speed range is insufficient to meet the set point, the engine selector will adjust the number of engines running by starting or stopping engines through the engine sequence controls.

The microwave tower atop Cheyenne Mountain, southwest of Colorado Springs, provides the link between Colorado Interstate's control center at its headquarters and the Springfield compressor station.

N. B. LauBach, left, vice president of operations for Colorado Interstate, and G. A. Peck, president of Southwestern Industrial Electronics Company, who participated in inauguration of remotely supervised automatic compressor station.

Changes in discharge and suction pressures and the number of engines on line are visible on the station monitor at the control center. This information also is typed out on an electronically-controlled typewriter in the control center.

Automatic equipment at the station controls all engine functions necessary to maintain the set pressure point. In addition to the engine control functions, there is a monitoring system that monitors all significant conditions requisite to safe operations.

Protective circuits have been provided with the thought in mind that if an operator in his routine duties would observe an "off-limits" condition, a protective device should be provided to detect the same condition.

In most instances instruments will detect off-limit situations faster and more accurately than a human operator and the design of Interstate's equipment takes full advantage of this. When any of these protective devices are activated, the proper engine or, if necessary, the entire station is shut down. At the same time, an alarm is signaled to the maintenance staff and the time and identification of the fault is recorded in an automatic log. This log also records each normal start and stop.

Digital telemetering, utilizing solid state electronics equipment, is used in Interstate's control system. This marks the first use of solid state electronics for natural gas compressor station control, the equipment being engineered and designed by SIE to Interstate's specifications. Engine start and stop sequencing equipment was designed by Stearns-Roger Manufacturing Company, Denver, and manufactured by SIE. The Cooper-Bessemer Company, Mount Vernon, Ohio, modified the compressors to make them compatible with the control system.

Installation and use of the automatic control system is the culmination of many years study by Interstate officials and engineers to determine the place of automation in the operation of a gas transmission system.

Interstate management plans to use the same type of automatic control at new stations proposed in the company's expansion program, which now is awaiting decision by the Federal Power Commission.

This expansion program, estimated to cost $91,000,000, will strengthen Interstate's Rocky Mountain transmission system capacity and also provide facilities for delivery of gas destined for the southern California market area.

Fig. 1. Station monitor.

CIG's NEW CONTROL SYSTEM: HOW IT WORKS

HUGH SAYE, *Marketing Manager, Control Division, Southwestern Industrial Electronics Company*

THE CONTROL SYSTEM built and installed on the Colorado Interstate Gas Company system by Southwestern Industrial Electronics Company, (SIE), a division of Dresser Industries, Inc., represents an approach to true gas transmission automation, and is designed for ultimate expansion into completely automatic operation where all routine computations and decisions will be "machine made" with human supervision.

The overall system design is such that, upon completion, the Colorado Springs Control Center will supervise and control 20 stations on the line.

Control at Point of Use

In the commercial operation of a natural gas transmission system, the major factors are supply, demand, and transportation.

For economic reasons the supply is held as constant as possible. Thus, with variable demand and constant supply, the transmission system must be able to provide the needed gas at peak demand and must be able to store the needed gas at peak demand and must be able to store the gas during periods of slack demand. This is accomplished by packing (raising the pressure) and unpacking (lowering the pressure) the transmission system. Therefore, the basis for operating a natural gas transmission system is pressure control.

Pressure control on a transmission system of this capacity is a complex process. It requires a great deal of computation and the consideration of many variables, such as the nature of the gas itself, its Btu content, the station altitude, the number of compressors on the line, their speed and compression ratio, line pack, and fluctuating demand.

Under manual operation and control each change in line pressure involves communication between points of measurement along the line and the control center. Computation, based upon this information, must then be relayed to the points of control where pressures are varied by changing the discharge pressure of compressor stations.

Because of the size and complexity of the engines and compressors, starting and shutdown require a timed sequence of events to assure safe operation. Under manual control this may require the services of from two to four men per station on a 24-hr basis. Station personnel are required to calculate the number of engines required, to start, stop, and control the speed of these engines as well as to open the shut valves to maintain a dispatcher-established discharge pressure set point. In addition the operators must be constantly on the alert for any off-normal conditions such as engines overheating, bearing failures, low oil pressure, power failure, explosive conditions in the station, etc.

The SIE Control System performs

Fig. 2. Data logger.

Fig. 3. Control center keyboard.

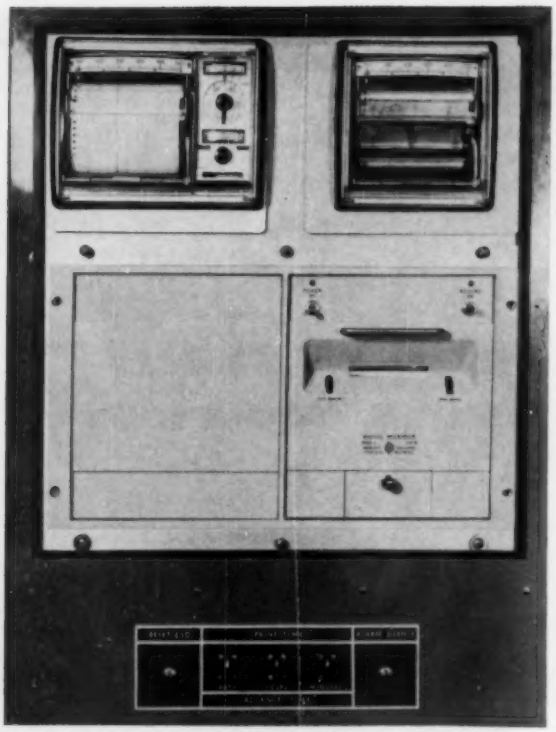


Fig. 4. Discharge pressure controller and log alarm shutdown.

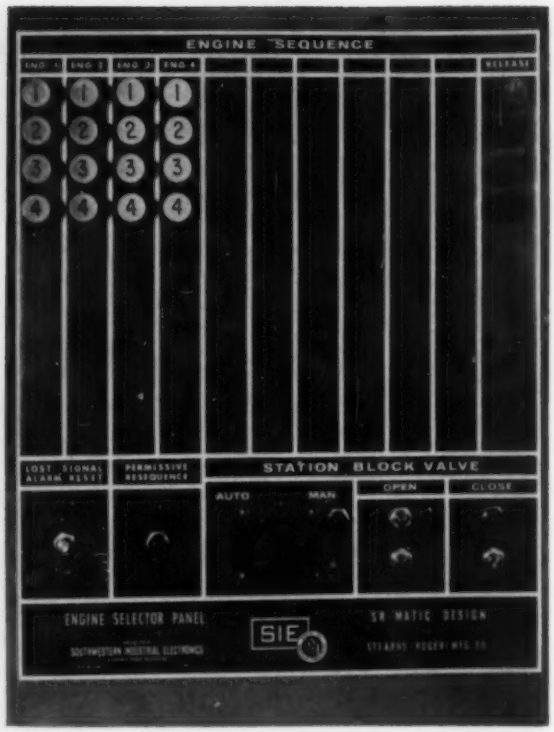


Fig. 5. Engine selector panel.

these routine tasks of station operation automatically. In addition, the system recognizes and takes into consideration all possible upset conditions on the line, maintains established discharge pressures by automatically regulating equipment, and monitors the mechanical equipment to provide complete fail safe operation in the event of an equipment failure.

The basic operating requirements placed on the system are:

1. The dispatcher must be able to direct a compressor station to automatically develop and maintain a certain discharge pressure by remotely transmitting only the discharge pressure set point to each station as desired.

2. Each compressor station must function, at all times, as a single self-controlled unit for the delivery of a desired discharge pressure in the most economical manner possible.

3. The dispatcher must have knowledge of the power being used at each station and the remaining power available.

4. The system must produce a printed log of compressor station variables and conditions at the control center. The logging operation is initiated manually or at selected, automatically programmed, intervals.

5. Operating manpower requirements for the pipeline must be minimized.

6. The safest possible operating conditions must be maintained at all times.

Let's follow one complete sequence using SIE's automatic supervisory control system.

Assume that the system dispatcher at Colorado Springs wants to increase the station discharge pressure to 850 psi.

Fig. 1 is the station monitor located at the Colorado Springs Control Center. A glance at the monitor informs the dispatcher of the Springfield station operating conditions. On it are various visual indications, such as a digital display of station suction and discharge pressure and station discharge pressure set point, the number of engines out of service (if any), and whether the station is locked out (out of service) or on manual control due to equipment failure.

On the data logger at the control center, Fig. 2, the dispatcher reads the complete story of the station conditions. The data logger is preprogrammed to print out at either 15, 30, or 60 minute intervals or on demand. The format is:

Time	Suction pressure	Discharge pressure
0130	550	750
Set point	Percent of speed	No. of engines running
750	75	3

To raise the Springfield station discharge-pressure the dispatcher initiates a new set point (850) at the control center keyboard, Fig. 3, by setting the station address and set point into the keyboard and pushing the transmit button. Internal circuitry converts the set point and station address into an electrical coded message that is transmitted to the station.

The addressed station (Springfield), upon receipt of the message, places the set point in storage and returns the message to the control center at Colorado Springs for verification. The transmitted and received messages are compared electronically at the control center and, if correct, a verifying message is transmitted to the Springfield station.

Set point verification having been received, the addressed station initiates a sequence of actions to bring the station discharge pressure up equal to the desired set point.

Discharge Pressure Controller

The desired set point, in the form of an electrical signal, is used as an input to the discharge pressure controller, Fig. 4, which utilizes two methods to obtain the correct output. Engine control provides discreet levels of horsepower so that the number of engines on the line is increased or decreased. Speed control provides continuously variable

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Fig. 6. Engine sequence.

ALARM IDENTIFICATION CHART

Individual Engine Alarms Identification	Log	Operation Alarm	Shutdown
Station Shutdown Alarms			
Fire Detector	X	X	X
Gas Detector	X	X	X
Station Discharge Pressure	X	X	X
Scrubber Level	X	X	X
Fan Vibration Switch	X	X	X
General Alarms			
Log Manual End	X	X	
Fuel Gas Pressure	X	X	
Selector Panel Power Failure	X	X	
Selector Panel Power Failure	X	X	
Starting Air Pressure	X	X	
Low Instrument Air	X	X	
Incomplete Sequence-Selector Panel	X	X	
Electrical Power to Standby	X	X	
Sequence Panel Power Failure	X	X	
Temperature Scan Group No. 1 (HI)	X	X	X
Temperature Scan Group No. 2 (LO)	X	X	X
Gas Discharge Temperature	X	X	X
Piston Overtravel	X	X	X
Lube Oil Level	X	X	X
Lube Oil Pressure	X	X	X
Lube Oil Temperature	X	X	X
Engine Vibration	X	X	X
Low Lubricator Flow	X	X	X
J. W. Temperature	X	X	X
J. W. Flow	X	X	X
Engine Overspeed	X	X	X
Stop Failure	X	X	X
Start Failure	X	X	X
Failure to Fire	X	X	X
Engine Started	X		
Engine Stopped	X		

Fig. 7. Alarm identification chart.

adjustment within the limits of the engines on the line. This is analogous to a "coarse" range control with an associated "fine" control continuously variable over the selected range. When the fine control cannot maintain discharge pressure equal to the set point, the coarse control then switches to the next higher or lower range to correct the situation.

The speed control (fine adjustment) is a closed loop, proportional-band controller. It consists of a discharge pressure transducer (pressure to electrical), an electronic proportional-band controller, and an electrical-to-air converter. The loop is closed through the engine governor to control engine speed.

The engine control (coarse adjustment) consists of three pressure switches, an engine selector panel and engine sequence panels. The pressure switches supply the engine selector with the information required for making the decision to start or stop an engine.

Upon receipt of a new set point, the discharge pressure controller, by comparison of signals, recognizes that a difference between actual discharge pressure and set point exists. The controller generates an "error" signal, which increases or decreases the speed of the engines on the line. If this change is not sufficient the controller sends a signal to the engine selector to add or subtract an engine. In our assumed case, increasing the speeds of the three engines did not raise the discharge pressure equal to the set point and another engine-compressor must be brought on line.

The engine selector, Fig. 5, monitors the governor-control air signal to determine the need for starting or stopping the engines, and provides start/stop signals to the engine sequence panels in accordance with an established engine selection program. Any engine may be placed in any position in the selector sequence. An "out-of-service" signal from a sequence panel automatically changes the selection sequence.

The engine selector, having decided that an engine must be started, checks the preprogrammed sequence and signals the proper engine sequence panel to bring its engine on line.

The engine sequence panel, Fig. 6, automatically cycles the engine on or off. Complete supervision of engine start-up or shut-down sequence is maintained. Each generated command is followed by appropriate action before the next command is given. Failure of the mechanical equipment to follow the prescribed action in a predetermined time initiates a "fault shutdown" and takes the engine out of service. When the engine sequence panel has completed the engine start up it signals the engine selector that the engine is on line.

After the engine selector has received this signal engine speeds are again varied to bring the discharge pressure to the set point.

Log-Alarm Shutdown

To insure safe operating conditions a Log-Alarm-Shutdown system (LAS) monitors station operation at all times, Fig. 4. Thus unit recognizes such things as "fire or combustible gas," excessive temperatures in the engine-compressors; lubricating oil level, pressure, and temperature; jacket water temperature and flow and many other station safety parameters. Fig. 7 is a chart listing alarms by group and indicates the action resulting if one of these conditions occurs.

The primary function of the LAS system is the immediate shutdown of affected equipment upon receipt of an alarm. Detection of an abnormal condition is instantaneous and the time from detection to initiation of a shutdown is approximately 1/10th second.

The secondary function of the LAS is to log the alarm that caused the shutdown. This is done on a digital printer, which automatically prints a coded message each time an alarm contact closes. The alarm printout contains date, time, engine number, and alarm conditions. A typical printout would be:

141118 0106

This tells the station operator that on the 14th (14) of the month at 11:18 A.M. (1118), engine number 1 (1) shutdown because of low lubricating oil pressure (06).

Engine alarms that result in a shutdown normally would require maintenance attention. Thus, when an engine

Fig. 8. Station power supply.

is shutdown by this means, it is locked out of service and a signal telemetered to Colorado Springs to inform the dispatcher that he has mechanical difficulties at the Springfield station. It is of no value to the dispatcher to know that the loss of an engine was due to low lube oil pressure or high bearing temperature. Thus the exact nature of the fault is not telemetered.

No reset of the LAS system is required except in the case of "Emergency Shutdown" (station shutdown). The other alarm circuits are self-restoring and will automatically reset when the off-normal condition is cleared.

The station power system (Fig. 8) consists of a 30-amp, magnetic-amplifier-controlled battery charger and 20 nickel-cadmium cells. In the event of power failure to the station, the 82 amp-hr capacity of the batteries is sufficient to keep the station operating for approximately 6 hr.

The station control equipment complement is housed in eight dust-proof (NEMA 12) enclosures, which are connected to form one large (20 ft) cabinet (Fig. 9). A wireway mounted across the top of these cabinets brings all customer connections for the compressor station and its auxiliary equipment into one terminal cabinet. All interconnections are made at the factory and the unit is tested as a complete station.

The system represents true automation, not remote control, as the entire station is controlled at the point of use. Once the operating parameters have been established, by the dispatcher, the system is entirely self-regulating.

Back at the control center, the dispatcher is informed through the station monitor (Fig. 10) that Springfield station is now at the desired discharge pressure. The data logger printout now reads:

	Suction	Discharge
Time	pressure	pressure
0140	550	850
Set	Percent of	No. of engines
point	speed	running
850	65	4

When the line is completely automated, the system will have a complement of five data loggers and may have a computer at the control center in Colorado Springs.

The system will log: Pressures, hourly volume, accumulated volume, hourly flow, average flow, Btu content, ambient temperature, percent rated engine speed (each station), number engines on line (each station), set point (each station), and computed sums of volume and flow. Continuously updated visual displays for each station giving suction and discharge pressure, set point, number engines out of service would be provided at Colorado Springs.

The completed system will scan the line and its 20 stations once every 4 min and will collect data on 160 variables. Logged data such as hourly flow, average flow rate, total hourly flow, total accumulated flow, etc., involves computation before it is logged. SIE's Automatic Supervisory System will perform these computations. If necessary, the dispatcher can have updated dynamic conditions along the line logged out as frequently as once every four minutes. Under normal operation the data logger would printout, on demand, or at 15, 30, or 60-min intervals.

The rapid data acquisition and high data density of SIE's Control System is compatible with high speed electronic computers. Planned for a later date some of the functions a computer would perform are: Figuring input volume, keeping track of movements of line pack and Btu content; ordering adjustments of station-pressure set points to make the line pack available at sales outlets in the proper quantity, at the proper time and at minimum cost. The computer would also figure overcapacity requirements and notify the dispatcher when, and how much, the curtailments to interruptible customers would be.

Freed from the necessity of manual communication with the stations, and constantly provided with updated information from points of control along the line, the dispatcher can make the decisions needed to provide his customers with the gas they need, when they need it. ★ ★ ★

Fig. 9. Station control equipment.

Fig. 10. Station monitor showing discharge pressure data.

GAS TRANSMISSION COSTS

(Effect of load factor and volume throughput)

Pressure Base: 14.9 psia

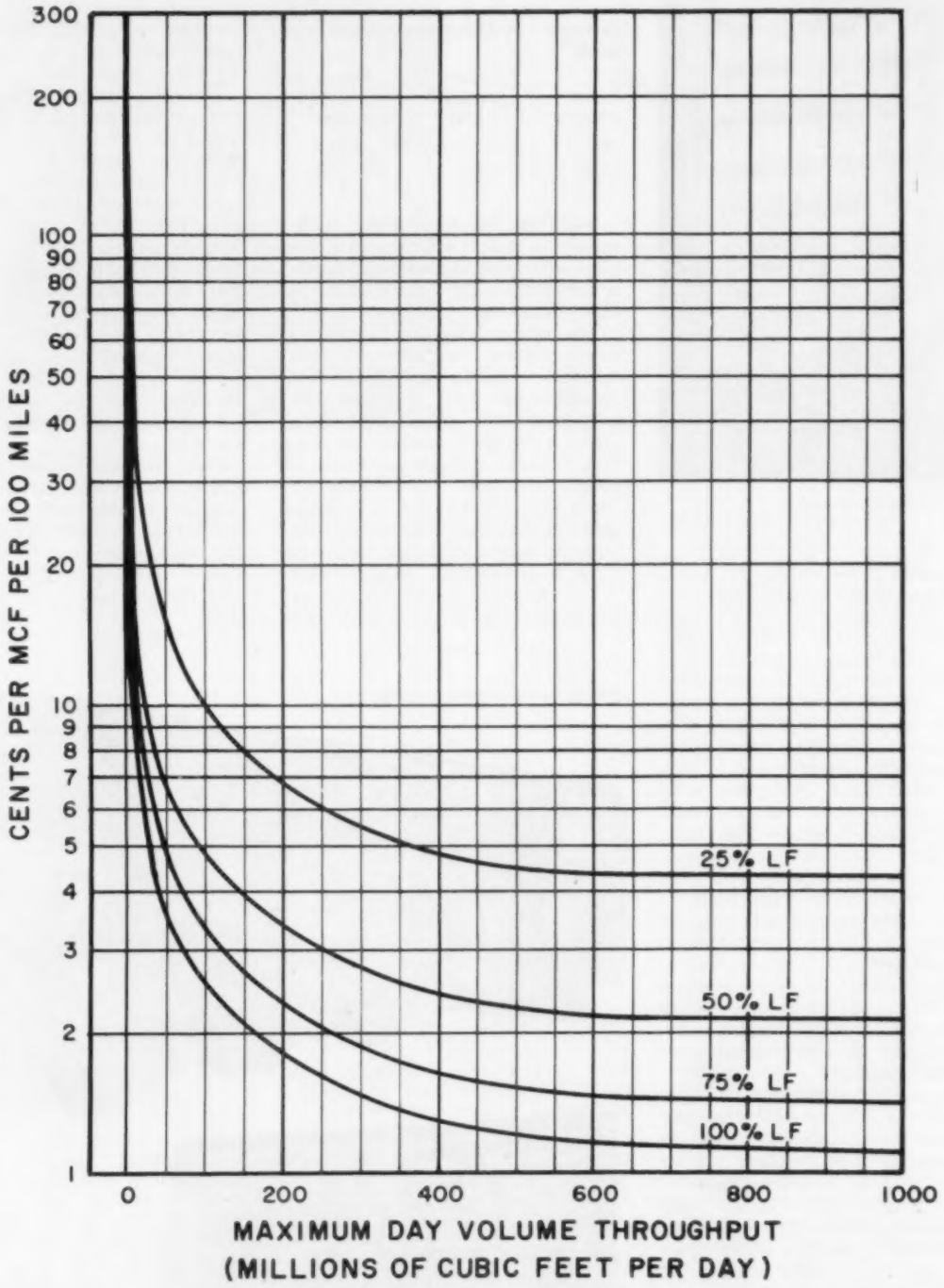
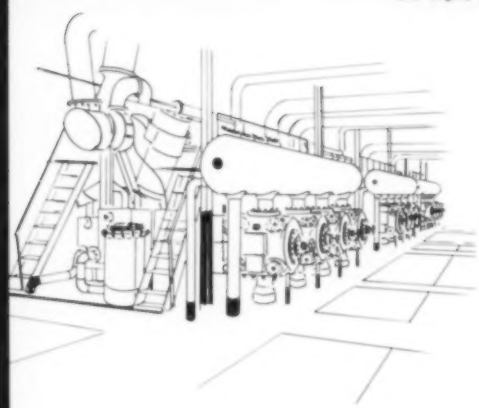


Chart courtesy Southern Counties Gas Company

This electronic compressor station analog, installed at Ingersoll-Rand's compressor and engine plant in Painted Post, N. Y., is now in use for piping analysis.



Taking the PULSATIONS out of a pipeline station

If you've ever seen compressor manifolds and piping resonate like an organ pipe, you know that gas pulsations can create serious problems which are costly and time-consuming to correct. But this evidence isn't always present to warn of piping troubles—the pulsations may be too small to shake the pipes, but still cause poor compressor performance.

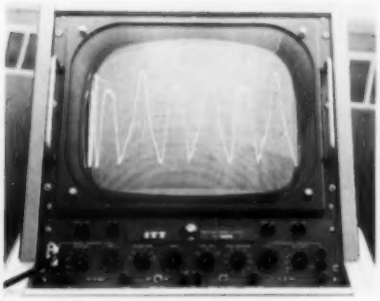
It involves long, complex calculations, by conventional methods, to design optimum manifold and piping arrangements for any compressor installation.

But now Ingersoll-Rand has taken the headaches and guesswork out of piping specifications, with the installation of a new "compressor station analog"—the most modern, most precise unit of its type in the world. By setting up an electronic simulation (or analogy) of any compressor installation, pulsation patterns and their effects can be predicted and measured with higher speed and accuracy than before possible.

(continued overleaf)

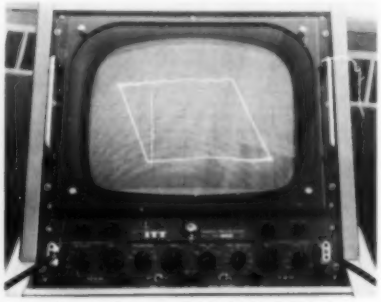
Ingersoll-Rand

How Ingersoll-Rand's **Compressor Station Analog** can prevent piping problems for you



This screen shows the pulsations which will occur at a selected point in a proposed compressor manifold and piping arrangement, indicating that changes should be made to prevent trouble.

The irregular indicator card pattern on this screen shows that pulsations in the system under analysis will cut down the efficiency of the compressor.



Here, using a corrected piping arrangement, the harmful effects of pulsation have been entirely eliminated, resulting in the correct pattern for top efficiency.

(see overleaf)

Designed and built especially for Ingersoll-Rand by the Southwest Research Institute of San Antonio, Texas, this electronic compressor station analog incorporates all the latest improvements which have been developed from experience with equipment previously supplied.

In operation, an electronic "model" of the compressor and its manifolds and piping is set up on the analog by means of plug-in components. Electric current is analogous to gas flow, and voltage is analogous to pressure. Compressor valves are simulated by diode tubes. Up to six cylinders may be simulated in any possible phase relationship, and any piping configuration may be set up for study.

On a calibrated oscilloscope screen, a visual pattern represents pressure waves taken from any point in the system. Another instrument makes a harmonic analysis of pressure variations and shows the size and frequency of each component. Indicator card diagrams of conditions inside the compressor cylinder may also be shown on a screen, for analysis of pulsation effects on compressor performance. Permanent records may be made by a camera attached to the analog. Various piping arrangements may be quickly tried on the analog to predict any faults, thereby preventing costly mistakes with the actual installation.

This analog has been made available solely for the benefit of Ingersoll-Rand's customers. In addition to *avoiding* problems on new installations, it can *diagnose* troubles in operating installations and permit quick remedy at minimum cost.

To take advantage of these facilities, get in touch with your Ingersoll-Rand engineer. You'll find him always ready to help with your other compression problems, too.

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11 Broadway, New York 4, N.Y.

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Form 3509

The World's Most Comprehensive Compressor Experience

Seeks 227-Mile Gas Line in Texas

El Paso Gas Supply Company is seeking Federal Power Commission authority to build 227 miles of 30-in. pipeline to enable it to transport 210,000,000 cu ft of gas per day for El Paso Natural Gas Company.

The proposed line would be built from a point near Three Rivers, Live Oak County, Texas, to El Paso Natural's existing Sonora plant in Sutton County, Texas.

The project, estimated to cost $31,000,000, also includes a 7000-hp compressor station to be built 2 miles east of Three Rivers, a river crossing, metering, and general structures and equipment.

El Paso Natural will purchase the gas from Houston Pipe Line Company and Coastal States Gas Producing Company at a point near Three Rivers and then deliver it to El Paso Gas Supply for transportation.

Storage Withdrawal Facilities Get "Temporary" Authorization

Natural Gas Storage Company of Illinois has received temporary authority from the Federal Power Commission to build facilities in Kankakee and Grundy counties, Illinois, to increase maximum day withdrawals to a total of 650,000,000 cu ft from the Herscher and Cooks Mills storage fields.

The company will drill two injection-withdrawal wells, construct a 0.56-mile, 36-in. pipeline crossing of the Illinois River, 0.3 miles of 10-in. gathering lines, and additional dehydration facilities, at an estimated cost of about $2,049,330.

The facilities will increase maximum day withdrawals by 75,000,000 cu ft.

Ajax Plans Gas Line Northwest of Edmonton

A natural gas pipeline in the area northwest of Edmonton, Alberta, to tie in the Morinville and Westlock gas fields in a single system is being considered by Ajax Alberta Pipeline, Ltd., principal gas line operator in the region, now operating 54 miles of line.

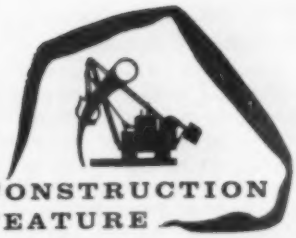
The company proposes to lay 28 miles of 10-in. pipeline to connect the Westlock field with its present terminal at Morinville, as well as 4 miles of 8-in. lateral.

If the Alberta Government issues a permit to build, construction would be next year following completion of long-term gas purchase contracts with Westlock producers. Gas reserves in the field are estimated at 250 billion cu ft. Ajax presently draws most of its gas from the St. Albert and Morinville fields.

Penn PUC Approves 52-Mile Gas Line

The Pennsylvania Public Utility Commission has approved a $5,220,000, 52-mile, 20-in. gas transmission line to be constructed by The Manufacturers Light and Heat Company to connect its system in the southern Pennsylvania counties of Franklin and Adams.

Manufacturers says it plans to build another 19-mile section later this year in Fulton and Franklin counties.



Pipeline Projects

Next Year Eyed for Westcoast Extension

Deferred until 1961 is the proposed extension of the main gathering system of Westcoast Transmission Company, Ltd., to Fort Nelson in northern British Columbia, according to an announcement by Frank M. McMahon, president. The line definitely will be built, however, at a cost of $100,000,000, as the first stage in a huge expansion program scheduled to cost $450,000,000 over the next five years.

Gas reserves in the four fields so far discovered at Fort Nelson are tentatively estimated at several trillion cubic feet, but exact calculations have not been feasible yet and engineering details of the line still are not settled.

The line will be 30-in. in diameter and approximately 250 miles long, running from Fort Nelson to Taylor, near Fort St. John, where the McMahon gas processing plant is situated. The plant will be enlarged concurrently with the construction of the gathering system extension. Eventually, the entire main line, which starts at Taylor and runs to Vancouver, will be looped at a cost of $250,000,000. The remaining $100,000,000 will be spent on field development and additions to the local gathering lines.

The new gathering trunk line will have capacity of 650,000,000 cu ft per day, more than the present main line capacity.

The entire project is said to depend on further development of export gas markets and expected steady growth of the British Columbia market. A permit will have to be secured from the B. C. Government but, because the line will be entirely within the province, no ruling will be required from the National Energy Board.

Dodsland Line Work Expected This Summer

The withdrawal of a competing application has cleared the way for Mid-Saskatchewan Pipe Lines, Ltd., to go ahead this summer with construction of a short, small-diameter crude oil pipeline to link the Dodsland field in west central Saskatchewan with its existing gathering system in the Coleville-Smiley fields.

Suffolk Enterprises, Ltd., a producer-owned company formed by operators in the Dodsland field, decided not to proceed with its application for a permit to build an 18-mile, 10-in. line directly to Interprovincial Pipe Line Company's pumping station at Kerrobert. The reason is believed to be lack of enough proved reserves to justify a separate line.

Mid-Saskatchewan's proposed line is 10 miles of 6-in. joining the present system at Coleville to give a direct connection with the main line of Interprovincial at Kerrobert.

Mid-Saskatchewan is a wholly owned subsidiary of Royalite Oil Company, Ltd., which recently disposed of its heavy gravity oil reserves in the Coleville field, retaining only the pipeline system.

TGT Offshore Facilities Given "Temporary"

Tennessee Gas Transmission Company has received temporary authorization from the Federal Power Commission to build about 11 miles of 12¾-in. pipeline and appurtenant equipment to take gas from its own production acreage in the Block 17 field, East Cameron area, offshore Louisiana.

The facilities are estimated to cost about $1,031,000.

Wins OK to Replace Portions of System

The Ohio Fuel Gas Company has received Federal Power Commission authorization to construct about 20 miles of 4½ to 24-in. pipeline, at an estimated cost of $1,225,250, to replace portions of its existing system in Medina, Fairfield, Perry, Pickaway, Clark, Montgomery, Warren, and Crawford counties, Ohio.

The new construction, the company said, is needed to assure adequate and economical service to existing markets.

"Temporary" Granted On Bayou Chevreuil Line

The Federal Power Commission has granted temporary authority, with Commissioner William R. Connole dissenting, to Texas Gas Transmission Corporation's proposal to connect a new source of natural gas supply to its system.

The construction includes a meter station and approximately 17 miles of 10-in. pipeline from the eastern terminus of its 20-in. line near Thibodaux, Louisiana, to the Bayou Chevreuil field, Lafourche Parish, Louisiana, at an estimated cost of about $965,200.

Replacements OK'd On Pennsylvania Line

The Federal Power Commission has authorized The Manufacturers Light and Heat Company's replacement project in Pennsylvania, but additional pipeline mileage is involved than was previously reported at the time the application was filed. (See *Pipeline Engineer*, May 1960.)

The FPC authorized the company to abandon 133.48 miles of 6-in. line and 131.03 miles of 8-in. line between Sideling Hill and Marietta, Pennsylvania, as well as the 700-hp Greencastle compressor station and the 1600-hp State Line compressor station, and to replace these facilities with 103.44 miles of 20-in. pipeline in Fulton, Franklin, Adams, Fayette, Somerset, and Greene counties, Pennsylvania. Estimated cost of the project is $7,703,000.

The construction is a continuation of the company's program of replacing old lines with a modern high pressure system.

Mississippi Crossing OK'd

Columbia Gulf Transmission Company's proposal to build a dual 24-in. underwater pipeline crossing of the Mississippi River near Lake Providence, Louisiana, to replace an existing crossing located about 1½ miles south, has received a "green light" from the Federal Power Commission.

The facilities will consist of 2.36 miles of 24-in. pipe and about 4 miles of 30-in. pipe.

Cost of construction is estimated at about $3,500,000.

FPC Approves "Budgets" Of Five Companies

Five companies have received budget-type authorizations from the Federal Power Commission permitting construction of natural gas pipeline facilities totaling $12,000,000. The projects, not related, will enable the companies to connect new supplies of natural gas.

Texas Gas Transmission Corporation, Michigan Wisconsin Pipe Line Company, and **Transwestern Pipeline Company** each are authorized to build facilities limited to $3,000,000 in cost, with each single project limited to $500,000.

Kansas-Nebraska Natural Gas Company, Inc., was authorized to build facilities having a total cost not in excess of $1,500,000, with the cost of any single project limited to $250,000.

Trunkline Gas Company was authorized to construct facilities not to exceed $1,500,000 in total cost, with single projects limited to $400,000.

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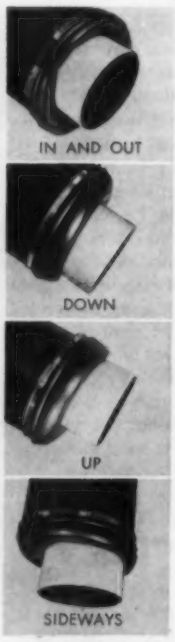

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REPRESENTATIVES AROUND THE WORLD

INTERNATIONALLY . . .

Colombia's first natural gas pipeline, construction of which is expected to begin in January 1961, will require approximately 140 miles of 10-in. steel pipe that should meet American Petroleum Institute specifications and be able to withstand pressures of 1000 to 1250 psi. In addition, valves, meters, and a gas compressor of 1000 to 2000 hp will be needed. Exact specifications on equipment desired and conditions of purchase may be obtained from Arthur Larsen, Colombian Petroleum Company, Apartado Aereo 3434, Bogota, Colombia.

In Saudi Arabia, Aramco's Safaniya-Ras Tanura line is getting a capacity boost with a new $11,000,000, 73-mile, 30-in. loop that will permit delivery of an additional 100,000 bbl per day lower-gravity crudes from the offshore Safaniya field and from Khursaniyah.

A Tunisia-Italy submarine pipeline is reportedly under study by Italian interests (Soc. Edison and Montecatini) and the Tunisian Government.

It's New PIPELINE EQUIPMENT

WORLD-WIDE NEW EQUIPMENT GUIDE
COMING JULY 15

The regular monthly NEW EQUIPMENT and NEW LITERATURE pages are omitted from this issue only. These popular features appear again in the August issue. Meanwhile, watch for the WORLD-WIDE NEW EQUIPMENT GUIDE, the latest and most complete reference manual of petroleum industry equipment, services, and products from around the world.

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PIPELINE PERSONALS

D. A. Roach

Named vice president of the newly organized Mid-America Pipeline Company is David A. Roach, a veteran of 14 years in the pipeline industry and former vice president of Phillips Pipe Line Company. **Robert E. Thomas** is president of the Tulsa-based company that is constructing a $71,000,000 products pipeline from Texas and New Mexico to cities as far north as St. Paul, Minnesota, and Madison, Wisconsin.

Okan Pipeline Company's vice president of operations, Gilbert V. Rohleder, has joined the new Mid-America Pipeline Company as general superintendent in charge of operations.

Frank G. Scott II, who started with Transcontinental Gas Pipe Line Corporation as an engineer at a Maryland compressor station and later was assigned to the engineering department in Houston, has been named assistant superintendent of the Transco gas control department.

Kaneb Pipe Line Company has elected **R. L. Staples** vice president-operations and a member of the board of directors. He joined Pipe Line Technologists, Inc., in 1952 as project manager in charge of constructing the original Kaneb products pipeline system and, upon its completion, was made general manager of Kaneb operations.

Elected to the board of Sinclair Pipe Line Company is **C. T. Carter,** director of engineering. He replaces **A. M. Stafford,** who has retired.

L. H. True, Magnolia Pipe Line Company president, has been elected a vice president and re-elected to the board of directors of South Saskatchewan Pipe Line Company, in addition to being named a director of Wyco Pipe Line Company. South Saskatchewan also named two other Magnolia Pipe Line Company executives as officials: **Ross Madole,** Magnolia's general attorney, was elected vice president and director; and **E. J. Wacker, Jr.,** vice president of Magnolia, was elected a director.

The Houston Corporation has increased its number of directors from seven to nine with the election of **J. French Robinson** and **John M. Harbert III.** Robinson was president and a director of Consolidated Natural Gas Company from 1943 until 1951 and was chairman of the board until his retirement in 1955. Harbert, who in 1954 joined the original group planning to bring natural gas to Florida and became a founding stockholder of The Houston Corporation, is president of Harbert Construction Corporation and Harbert and Cargil, Inc., and vice president of Mill Ridge Coal Company.

Service Pipe Line Company has transferred Tom Hopson, engineer, from the electrical section in Tulsa to the company's east Texas division to replace **J. C. Peard** who has been assigned to Baytown, Texas.

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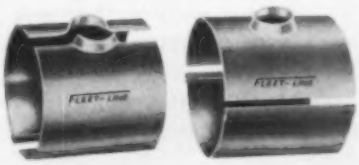

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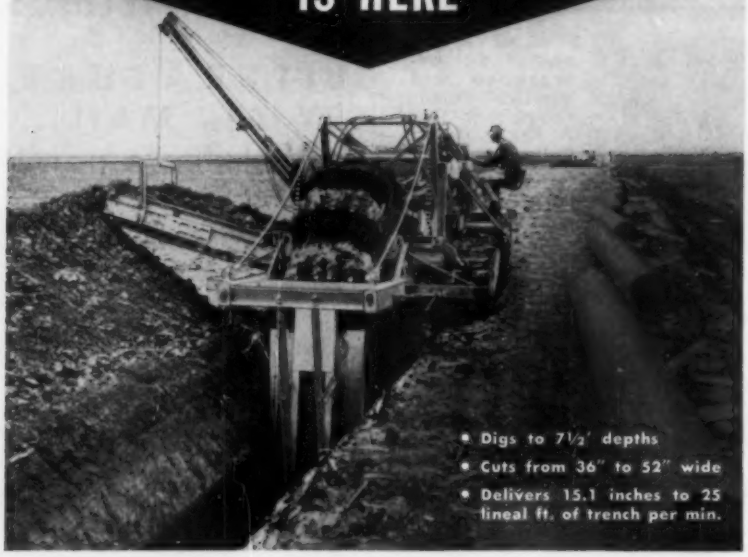

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PIPELINE PARADE

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Robert O. Vaughan, well-known electronics executive, has been appointed vice president, marketing, of **Southwestern Industrial Electronics Company,** one of the Dresser Industries, and moves into the SIE position from his former post as western regional manager of government operations for Dresser Industries, Inc. Vaughan's 20 years' experience covers affiliations with RCA, The National Aircraft Corporation, and Hoffman Laboratories.

SIE also has appointed Bernard W. Eades, formerly with Stromberg-Carlson Company, as manager of value engineering. W. A. Laukaitis, formerly manager of W. L. Maxson Corporation's Washington office, has been named eastern regional marketing manager for SIE.

R. O. Vaughan

G. W. Prager

Standard Pipeprotection, Inc., has appointed a sales representative for Colorado, Wyoming, Montana, Utah, and Idaho. He is G. W. (Wally) Prager, formerly with the E. W. Robinson Supply Company, pipeline suppliers.

The Houston-headquartered Coast Paint and Lacquer Company, engaged in corrosion control for gas transmission pipelines, has merged with Reliance Varnish Company of Louisville, Kentucky, and plans expansion of production facilities and personnel of the Houston plant up to 40 percent within the next 18 months.

Reliance board chairman H. C. Grawemeyer and Coast Paint board chairman Kenneth W. McDowell made the joint announcement.

A new vice president, responsible for production and distribution of industrial gases, has been appointed by **Air Reduction Sales Company.** He is J. M. Crockett who has been associated with Airco since 1945 and was most recently manager of the company's Birmingham district office.

The steel fabricating firm, Master Tank and Welding, has appointed Holly Bird as representative to specialize in sales of storage, transport, local delivery and domestic tanks in West Texas and New Mexico.

WITH THE PIPELINE CONTRACTORS

● **Banister Construction Company, Ltd., 625 Northern Hardware Building, Edmonton, Alberta, Canada.** Is constructing for *Alberta Gas Trunk Line Company, Ltd.*, a 72-mile, 24-in. pipeline between Torrington and the Rimbey gas plant. Field office is located in Red Deer, Alberta, and George Caron is superintendent.

● **O. R. Burden Construction Corporation, P. O. Box 5216, Tulsa, Oklahoma.** Has been awarded a joint contract with H. B. Zachry Company to construct *Old Ocean Fuel Company's* 370-mile natural gas pipeline between the Gulf Coast area, south of Houston, Texas, to the Fort Worth area. Spread No. 1, consisting of 92 miles, begins at Washington County and ends at Limestone County, under the supervision of R. M. Jones. Spread No. 2, consisting of 92 miles, begins at Limestone County and ends at Fort Worth, under the supervision of C. M. Hoffman.

● **Sam Carline, Inc., Box 138, Berwick, Louisiana.** Is constructing for *Transcontinental Gas Pipe Line Corporation* 6300 ft of 7, 8, and 10-in. pipeline, plus various risers and platform connection work, 25 miles offshore, Block 77, Vermilion area, Louisiana, with Ray Austin supervising. Has been awarded a contract to lay various flowlines for *Shell Oil Company* offshore, Block 18, Eugene Island area, Louisiana, under the supervision of Warren Stockstill. Has received a contract to construct a 12-in. crossing of the Atchafalaya River, north of Baldwin, Louisiana, for *Texas Gas Transmission Corporation*.

● **Collins Construction Company, P. O. Box 86, Port Lavaca, Texas.** Has in progress the construction of dual 12 and 24-in. natural gas pipeline river crossings for *Petroleos Mexicanos* between Pemex City and Mexico City in Mexico. Field office is in Minatitlan, Mexico, with Rug Stapleton as project manager.

● **Contracting and Material Company, 1235 Dodge Avenue, Evanston, Illinois.** Has received a contract to construct for *Northern Illinois Gas Company* a 73-mile, 30-in. natural gas pipeline between Troy Grove and Aurora, Illinois. Field office will be at Earlville. Arthur J. Fry has been appointed superintendent.

● **Farmer Construction, Ltd., Box 4253, South Edmonton, Alberta, Canada.** Has received a stringing and boring contract from Banister Construction Company, Ltd., on *Alberta Gas Trunk Line Company's* 72-mile, 24-in. pipeline from Torrington to the Rimbey gas plant.

● **Hall Construction Company, 1105 N. Carlton, Liberal, Kansas.** Is working on a 330-mile, 4 through 12-in. gathering system in western Kansas for *Panhandle Eastern Pipe Line Company*. Supervising are Mike Bell and M. E. Banning.

● **Hood Construction Company, 8201 South Sorensen Avenue, Whittier, California.** Has in progress a joint venture with J. P. Neill Company and River Construction Corporation involving the construction of 32 miles of 36-in. pipeline between Cucamonga and Placentia, California, for *Southern California Gas Company* and *Southern Counties Gas Company*. Cecil Jernigan and Merle Tatum are supervising at Chino, California. Another joint venture with River Construction Company has been awarded by *El Paso Natural Gas Company*, involving 120 miles of 10, 12, 16, and 20-in. pipeline from Portland to Eugene, Oregon. Field offices are at Camas, Washington, and Oregon City, Oregon, under the supervision of Bill Burgess and Vernon Gehart.

● **Houston Contracting Company, 2807 Buffalo Speedway, Houston 6, Texas.** Has been awarded a contract by *Michigan-Wisconsin Pipe Line Company* to build 92 miles of 24-in. pipeline in Wisconsin. Headquarters will be at New London, under the supervision of R. L. Silar. Has been awarded a contract by *Shell Pipe Line Corporation* to lay 3 miles of 10-in., 3 miles of 22-in., 3 miles of 22-in. reconditioned line across the proposed Oologah Reservoir in Rogers County, Oklahoma. A. J. Slovak will supervise, and Nowata will be the site of the field office. Has been awarded a contract by *Midwestern Gas Transmission Company* to construct two new compressor stations and 21 meter stations in Minnesota, North Dakota, and Wisconsin. S. C. Downing will supervise at Noyes, Minnesota, and J. J. Noland at Staples, Minnesota. Has been awarded a contract by *Southern Natural Gas Company* to lower and case 20 and 24-in. main lines east of New Orleans, Louisiana. Field office is at New Orleans, and R. E. Thornton is spreadman.

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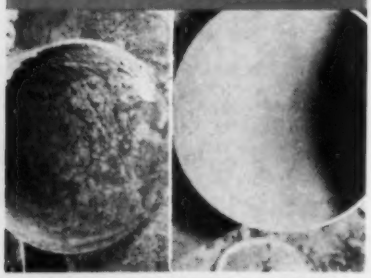

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● **Hunsaker Trucking Contractors, Inc., Box 97, Carrollton, Texas.** Has been awarded stringing contract on the *Old Ocean Fuel Company* natural gas pipeline between the Gulf Coast area, south of Houston, Texas, to the Fort Worth area. Is working on 70 miles of 16-in. and 30 miles of 20-in. for H. B. Zachry Company between Graham and Fort Worth. One field office is located at Springtown under the supervision of Buster Cooper, and another at Fort Worth under the supervision of B. P. Beard. Is working for O. R. Burden Construction Corporation on 183 miles of 24-in. between Brenham and Fort Worth, with Johnny Utsey supervising at Brenham and R. H. Buchanan supervising at Mexia.

● **Joyce Pipe Line Company and Joyce Western Corporation, Box E, Andover, New York.** Is constructing for *Peoples Natural Gas Company* 8 miles of 20-in. pipeline from Imperial to Aliquippa, Pennsylvania, and 4 miles of 6-in. in the vicinity of Cresson, Pennsylvania, under the supervision of L. Ostrander.

● **Lasley Construction Corporation, Box 1465, Hobbs, New Mexico.** Is constructing for *Phillips Petroleum Company* an 85-mile, 2 to 16-in. gathering line in Eddy County, New Mexico.

● **Latex Construction Company of Georgia, Box 12128, Atlanta, Georgia.** Has been awarded a contract to recondition for *Plantation Pipe Line Company* approximately 60 miles of 4-in. and 40 miles of 12-in. pipeline. Thomaston, Georgia, is headquarters site, and J. M. Phipps and G. H. Matlock are superintendents.

● **Mannix Company, Ltd., 737 - 8th Avenue, S. W., Calgary, Alberta, Canada.** Is constructing 94,000 ft of 30-in. pipeline for *British Columbia Electric Company, Ltd.*, between Huntingdon and Livingston Road and 46,000 ft of 20-in. in the Burrard Inlet area. V. J. Worcester is superintendent and field office is at Abbotsford. Is constructing the Kenora, Ontario, compressor station with building extension at Port Arthur for *Northern Ontario Pipe Line Crown Corporation*. J. Hobbs is superintendent.

● **J. P. Neill and Company, 522 Meadows Building, Dallas, Texas.** Has been awarded a joint contract with Hood Construction Company and River Construction Corporation to construct for *Southern California Gas Company* and *Southern Counties Gas Company* 32 miles of 36-in. gas pipeline between Cucamonga and Placentia, California.

● **Ohio Pipe Line Construction Company, Box 29, Newark, Ohio.** Has been awarded a contract by *Ohio Fuel Gas Company* to remove approximately 40,000 ft of 18-in. pipe and lay the same amount of 24-in. pipe. The field office is located at the Montgomery County airport near Waynesburg, Ohio. T. H. Ralston is superintendent.

● **Panama Williams Corporation, 1418 Melrose Building, Houston, Texas.** Has been awarded a contract by *Michigan-Wisconsin Pipeline Company* to lay approximately 115 miles of 4, 6, and 8-in. pipeline in loops in the vicinity of Stevens Point, Wisconsin. Field office is located at Antigo, Wisconsin. Superintendents are Emmett Sutton and Ned McElmurray. Has been awarded a contract to build 14 miles of 22-in. pipeline between Samaria, Michigan, and Toledo, Ohio, and a crossing of the Maumee River near Toledo for *Buckeye Pipe Line Company*, has appointed

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W. H. Shiflett and Emmett Sutton superintendents, and located field office near Monroe, Michigan.

● **Pentzien, Inc., 1504 Dodge Street, Omaha, Nebraska.** Has been awarded a contract by *Texas Eastern Transmission Corporation* to install a single 20-in. Arkansas River crossing near Little Rock, where field office will be located under the supervision of James E. Garner. Has received a contract from *Arkansas Industrial Pipe Line Corporation* to install a dual 18-in. Arkansas River crossing near Wright, Arkansas. Superintendent is T. D. Stout; field office is at Pine Bluff, Arkansas.

● **Pipe Line Technologists, Inc., 3431 Alabama, Houston, Texas.** Has a contract to construct for *Seadrift Pipeline Corporation* a 108-mile products line from Union Carbide Corporation's Seadrift, Texas, plant to Humble Oil & Refining Company's King Ranch plant at Ella, Texas.

● **H. C. Price Company, Price Tower, Bartlesville, Oklahoma.** Is double jointing 154 miles of 24-in. pipeline for *Midwestern Gas Transmission Company* in Minnesota, with Don Barcus as foreman.

● **River Construction Corporation, Box 9127, Fort Worth 7, Texas.** Has been awarded a joint contract with J. P. Neill and Company and Hood Construction Company to construct for *Southern California Gas Company* and *Southern Counties Gas Company* 32 miles of 36-in. gas pipeline between Cucamonga and Placentia, California. Has been awarded a joint contract with Hood Construction Company to construct for *El Paso Natural Gas Company* 120 miles of 10, 12, 16, and 20-in. gas pipeline from Portland to Eugene, Oregon.

● **Rosson-Richards Processing Company, Box 35037, Houston 35, Texas.** Has been awarded contracts by *Midwestern Gas Transmission Company* to internally clean and paint 123.8 miles of 24-in. pipe at U.S. Steel's plant at McKeesport, Pennsylvania, under the supervision of J. E. Hood and H. Woodard, and to yard coat 52 miles of 24-in. at Donaldson, Minnesota, and 53.1 miles of 24-in. at Euclid, Minnesota. Has received contract from *Houston Contracting Company* to coat and wrap and Wate-Kote 10 miles of 10 and 22-in. pipe at Talala, Oklahoma, under the supervision of J. Alexander.

● **Stanley-Bledsoe Corporation, 612 Daniel Building, Tulsa 3, Oklahoma.** Has been awarded a contract by *Trunkline Gas Company* to double joint 78 miles of 30-in. pipe in Mississippi, Tennessee, and Louisiana. Has been awarded contract to construct 3 and 4-in. lateral lines, extending *Natural Gas Pipeline Company of America's* gathering system in Jack and Wise counties, Texas. Has been awarded a contract to internally clean and coat 150 miles of pipe for *Midwestern Gas Transmission Company's* 24-in. pipeline from Emerson, Manitoba, to Marshfield, Wisconsin. Headquarters for the work is Gadsden, Alabama.

● **Turriff-Burden, Ltd., (subs. Burden International, Ltd., Box 5216, Tulsa, Oklahoma).** Has been awarded a contract by the *Iraq Petroleum Company, Ltd.*, for the construction of 315 miles of 30 and 32-in. pipeline from Kirkuk to the Syrian border and connecting Rumaila and Fao. The project office in London, England, will be managed by W. T. Barker. Field construction superintendent is John H. Miller; assistant superintendent is Arnold Smith; and manager of the field office in Baiji, Iraq, is G. E. Suagee.

INTERNAL-EXTERNAL PIPE COATING...
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● **Steico, Inc., 905 Barton Springs Road, Austin, Texas.** Has been awarded a contract by *El Paso Natural Gas Company* to lay an undetermined amount of various size lines in the Shamrock field under the supervision of Al Blanchard and W. K. Hancock.

● **Western Pipe Line, Inc., Box 1076, Austin, Texas.** Has been awarded a contract by *El Paso Natural Gas Company* to lay 52 miles of 20-in. main line and 8 miles of 8-in. gathering line in Pecos and Terrell counties, Texas, under the supervision of Clint Schell.

● **Williams Brothers Company, National Bank of Tulsa Bldg., Tulsa, Oklahoma.** Has been awarded a contract by the *National Iranian Oil Company* to construct a 240-mile, 8-in. petroleum products line in Iran from Rey, near Tehran, northeast to Sharud. Is laying a pipeline for *Mid-America Pipe Line Company* and announces the start of construction for two more spreads: Spread 3, under Superintendent James Martindale, is headquartered at Tampa, Kansas, and will lay 340 miles of 8-in. line from Conway, Kansas, to Macon, Missouri; Spread 4, under Superintendent Tubby Boyd, headquarters at Hurdland, Missouri, and will lay 60 miles of 8-in. line and 290 miles of 6-in. line from Macon, Missouri, to Madison, Wisconsin. Has been awarded a contract by *The Manufacturers Light and Heat Company* to lay 70 miles of 20-in. pipeline from Abbotstown to Warfordsburg, Pennsylvania. Gettysburg is field office site, and Thelmer Davis is superintendent. Has been awarded a contract by *Atlantic Seaboard Corporation* to lay 45 miles of 20-in. pipeline from Terra Alta to Seneca station in West Virginia, with Earl Saulsman supervising.

● **Young and Anderson Company, Box 68, Brea, California.** Has been awarded a contract by *Southern California Gas Company* and *Southern Counties Gas Company* to build approximately 85 miles of 36-in. pipeline from Newberry to Cucamonga, California. Jack Cook and R. R. "Ronnie" Cook have been named project superintendents.

● **H. B. Zachry Company, Box 10188, San Antonio 21, Texas.** Has been awarded a joint contract with O. R. Burden Construction Corporation to construct *Old Ocean Fuel Company's* 370-mile natural gas pipeline between the Gulf Coast area, south of Houston, Texas, to the Fort Worth area.

Write for Bulletin

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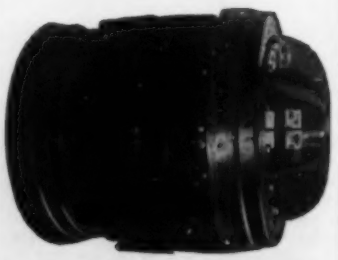

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